New trends in biology teaching

Volume IV

The teaching of basic sciences

Biology

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The teaching of basic sciences

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Preface

Within Unesco's programme to foster the improvement of science education at all levels, and in all regions of the world, promotion of the international exchange of ideas and information plays an important role. As one means of encouraging this exchange, Unesco initiated the publication of a series on 'The Teaching of Basic Sciences'. Three or more volumes in this series have so far appeared for each of the disciplines of mathematics, physics, chemistry and biology. These volumes are intended for all those concerned with improvement in the teaching of the particular science-teachers in universities and teacher training institutions, officials of ministries of education, secondary school teachers, students preparing to become science teachers, members of examination boards, school inspectors, science teachers' associations, etc.

The present volume is the fourth in the series *New Trends in Biology Teaching*, the first having appeared in 1967, the second in 1969 and the third in 1971. The first three volumes represented experiments designed to determine the best means of disseminating useful information on modern content, approaches, curricula and techniques in the teaching of biology among the maximum number of science educators at minimum cost and as rapidly as possible. Hence each volume contained not an analysis of trends in biology education but a mixture of reprinted materials (e.g. summary reports of important seminars or conferences and articles from leading journals) together with original articles and supplementary factual information.

Although all the first three volumes of *New Trends in Biology Teaching* were well received, it was felt that it would be even more useful henceforward to publish volumes containing actual analyses of trends and problems in various aspects of biology education as revealed by detailed study of the recent relevant literature; to print separate language versions of each publication (at least English, French and Spanish); and to issue a volume at the rate of one every four or five years. The present volume of *New Trends in Biology Teaching* has been prepared in accordance with this new policy and therefore differs in content and approach, but not in purpose, from the preceding volumes in the set.

The designations employed and the presentation of the material in this work do not imply the expression of any opinion whatsoever on the part of the Unesco Secretariat concerning the legal status of any country or territory, or of its authorities, or concerning the delimitation of its frontiers.

The opinions expressed in the following pages, moreover, are those of the authors and do not necessarily reflect those of Unesco.

Contents

Introduction

The main objective of Unesco's pre-university science and technology education programme is to organize and promote activities leading to the improvement of the teaching of science disciplines at pre-university level. The Organization's aim in this field, particularly with regard to developing countries, has been to introduce improved teaching programmes for each particular discipline on a regional basis.

As regards biology, the African continent was chosen for the implementation, between 1967 and 1972, of a pilot project for the improvement of education in this discipline. Important results have been obtained thanks to the co-operation of the national study groups set up in African countries, to training courses and seminars lasting from a few weeks to several months and, finally, to the co-operation of experienced African and other specialists and educators. Among the latter are the members of the Commission for Education in Biology of the International Union of Biological Sciences IUBS.

In order to support national efforts in educational renewal, covering the improvement not only of the content and methods of teaching programmes but also of teacher training, and above all the adaptation of education to its social and cultural context, Unesco, with the financial assistance of, and in co-operation with, the United Nations Fund for Population Activities (UNFPA), prepared in 1971-1973 and published in 1975 a *Teacher's Guide on the Biology of Human Populations* for Africa and Asia. A version for Latin America will be published in 1977. Its aim is to provide biology teachers with source material concerning the many implications of population changes, especially the possible consequences of demographic growth, and the relations between man and his milieu, based on a solid background of scientific knowledge which they are constantly called upon to teach in the new courses.

Meanwhile and parallel to this effort at making biology teaching more relevant to the needs of Unesco member states, the publication of the work entitled *New Trends in Biology Teaching* (three volumes of which have been published) was designed to disseminate information concerning international activities for the renewal of biology teaching. This series is a singularly useful instrument for communication between countries and a valuable source of information for all those concerned with biology education. Moreover, in order to identify and analyse the recent trends and present problems of biology education at all levels and of all types, especially over the last four to five years, and to prepare a four-year co-operative plan of action involving international, regional and national organizations for the further improvement of biology education, an international congress was organized by the Commission for Education in Biology of the IUBS under contract with Unesco, in collaboration with the Teacher Training College of the University of Uppsala, in Uppsala, Sweden, 8 to 12 September 1975.

To achieve the Congress objectives, the overall subject of biology education was divided into twelve topics or areas. For each of these, a trend paper was prepared in order to:

- review, summarize and analyse developments and trends, as revealed by the existing literature and other documents from all parts of the world;
- identify the issues, problems and challenges revealed by the analysis of the situation;
- suggest the forms of co-operative action needed to solve these problems and meet these challenges;
- include a selective bibliography for those wishing to read further on the subject.

Every author was therefore asked not to add just one more article to the already extensive literature on biology education, but rather to make a scholarly analysis and summary of the existing literature and trends.

The trend papers were discussed in detail by concurrent working groups during the Uppsala Congress, in the presence of the respective authors. Besides revising the content of the paper in respect of the level (primary, secondary, university, etc.), the type (formal, non-formal), the aspect (objectives, methods, evaluation, etc.) of the concerned domain of biological education, the working groups were very helpful in bringing to the attention of the authors of the trend papers, information from various parts of the world in order to intensify the international approach. Moreover, discussions allowed for the submission of several recommendations and proposals for action pertaining to the various topics and areas under discussion.

The revised trend papers were edited with due regard to the need stressed by Unesco and the IUBS Commission for Education in Biology for a balanced, scholarly and clear statement about what has been done and what is being done, with a satisfactory geographical representation of the examples used; and at the same time to have feasible and realistic proposals for action to guide Unesco's activities in the coming years. The editorial work was also concerned, as usual, with the correct sequence of the papers, the necessary cross-reference between them, the avoidance of unnecessary overlapping, so that the reader is given a logical sequence of topics and studies, and at the same time a faithful picture of the input of the Congress. The editors are fully aware of the differences existing between the various chapters of this book, but they consider these as a positive aspect reflecting the specific viewpoints of the contributors.

The revised and edited trend papers now constitute the chapters in this fourth volume of the work *New Trends in Biology Teaching.*

1. Trends in the purposes and objectives of biological education.

This chapter deals with purposes and objectives in a general and global sense. It analyses recent literature concerned with the general question of 'why teach biology?' not only to the professional biologist and others who need it in their careers but also to the general citizen (for instance, through out-of-school programmes for adults and youths alike). This chapter identifies controversial and/or unresolved issues concerning the purposes of biology education.

2. Trends in the biological component of education at the primary and junior secondary levels.

This chapter reviews the literature in respect of all questions arising from the inclusion of elements of biology (including human and social biology) in science courses, primarily at the early school levels – the objectives, the methods, the special problems, preparation of teachers, problems of 'integration', etc.

3. The development and design of new courses in secondary biological education.

The enormous advances in knowledge in biology have resulted in the traditional ways of organizing and teaching this knowledge being challenged. This chapter reviews trends and patterns of the recent past as well as problems and present issues concerning the changing of biology courses, at secondary level, in the light of new knowledge.

4. Curriculum evaluation and dissemination.

This chapter focuses **not** on the **product** of curriculum improvement efforts in biology but on the **processes** or techniques, that are used for evaluating and disseminating new programmes and courses. There is a big difference between developing some improvement in biology education (course, or syllabus, or textbook, etc.) and ensuring that it is diffused and adopted throughout a national educational system. Success in this dissemination, of course, depends heavily upon factors peculiar to each country – relevant laws and policies, decision-making structures, the degree of autonomy of universities and school systems, the level of national development, etc.

Nevertheless, there are probably lessons to be learned from a comparative analysis of the varying approaches (and the success thereof) in different countries. The chapter summarizes experience in this area.

5. The understanding of the learning process and the effectiveness of teaching methods in the classroom, laboratory and field.

Although science has been taught for a very long time, relatively little has hitherto been known about the psychological processes by which students learn such fundamentally different things as scientific concepts, principles, attitudes, skills, facts, etc. Research on these learning processes continues and the results are having some effect on approaches to the teaching of biology. Without emphasizing previous well-known facts and theories (Piaget, Skinner, etc.), this chapter reviews recent research findings and their effect on the teaching of biology, together with current issues and needed research.

6. The impact of new instructional equipment and educational technology in the process of teaching biology.

This chapter summarizes world-wide experience with all types of new devices and resource materials that can be used to facilitate the learning of biology. Examination of the role of educational technology covers not only complex and sophisticated systems but also simple devices useful in the least affluent circumstances. Examples of the former include computer-assisted instruction, broadcast and closed-circuit television, videotapes and cassettes, single-concept film loops, programmed materials, improved audio-visual equipment and materials, etc. Attention is given not only to what the new 'hardware' theoretically makes possible but also to the degree of success in actually utilizing it and in generating the necessary 'software'. The chapter also concerns itself with developments and trends in inexpensive equipment, kits, and other learning resources.

7. Trends in techniques and criteria used in assessing student achievement.

Many efforts to improve science education have been rendered relatively ineffective by rigid and out-dated examination systems, by tests which have not been modified in type and content in the light of new objectives, new methods and new materials. This chapter not only examines trends and problems, at various levels of biology education, in adapting tests and examinations to such changes, but also summarizes the consequences for biology education of new developments in the field of educational tests and measurements. It stresses the role of assessment in the daily contacts between teacher and students.

8. Developments in the training and retraining of school biology teachers.

Recent innovations in science education at various levels, particularly the secondary, involve changes not only in what the student is expected to learn but also in the role of the teacher in promoting this learning. Both types of changes would necessitate modifications in the pre-service and in-service training of teachers. This chapter summarizes trends, problems, issues in this area – the balance between biology and pedagogy in the pre-service training of teachers, whether future teachers learn biology in the way they will be expected to help their students learn it, experience in changing the behaviour patterns of teachers through various types of in-service training, etc. The chapter emphasizes the link which should exist between pre- and in-service training.

9. Trends and problems in designing introductory university-level biology courses.

Numerous developments have required special attention to biology courses at the introductory university level – large increases in enrolments, shortages of equipment and laboratories, changes in the prior knowledge of students (as a result of improvements in biology education at

the secondary level), shortage of teaching staff, etc. This chapter summarizes relevant trends and problems in all aspects of introductory university biology courses and outlines further action needed in this area.

10. The contribution of biology to public interest and to public education.

This chapter concerns the biology component of all activities that take place outside formal educational programmes and are intended to help the ordinary citizen learn about science so that he may contribute adequately to modern society. It considers not only out-of-school activities for youth (science clubs, science fairs, etc.) but also various media (museums, zoological parks, public lectures, radio, television, and newspapers, etc.) intended for the public at large. The chapter deals with what these activities should aim to present (facts or concepts, attitudes or what?), and the special educational techniques required in view of the diverse background and interests of the audience. It also considers the special difficulties of evaluating the effectiveness of such programmes.

11. Regional and international co-operation for the improvement of biology education.

An overall review of trends in the improvement of biology education would be incomplete without an examination of the status, trends and needs in regional and international co-operation in this area – the role of the United Nations agencies, of international and regional associations of biologists and/or educators, of foundations, bilateral aid organizations, industrial groups, etc. The chapter includes recommendations for future action in the light of past experience.

It was originally intended to include in the present volume a chapter on 'Designing courses to meet the changing conditions and requirements for the professional use of biology in basic and applied sciences', prepared for discussion at the Congress by Prof. Adnan Badran, Dean of the Faculty of Science, University of Jordan, Amman. Unfortunately, the revised version of Prof. Badran's paper reached us too late for inclusion.

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Truth and enthusiasm in biology education

by Kenneth Mellanby

The purpose for which we have met at this Congress is to try to improve biology education. This assumes that biology education is a good thing, but that we must nevertheless try to make it even better. I fully agree with both these propositions. I believe that biology should play many different parts, at different levels, in all types of education. However, I shall concern myself here with only two topics, chosen because they are ones in which biology education should play a predominent part. First, I shall speak about the environment, a subject of concern to us all, and one where the biologist should make a particular contribution – but where biologists (and pseudobiologists) often talk dangerous nonsense. The second topic concerns food – man's needs and his ability to produce sufficient food is clearly a problem which faces every individual on earth today and in the future.

My title, 'Truth and enthusiasm in biology education', may need some comment. We all know what we mean by truth, we all think it is a good thing. Nevertheless, absolute truth may be difficult to achieve, and most difficult of all may be the establishment of the difference between truth and opinion. In teaching we all set out to teach truth rather than error, but do we always succeed? Are we always clear when we are putting forward our prejudices rather than a description of the facts? And does it matter?

The word enthusiasm has a more dubious origin. In earlier days it meant 'possessed by a God' – and the assumption was that he was not a very good or orthodox deity. Established churches were very suspicious of any sort of enthusiasm, believing that it commonly led to heresy. Today, enthusiasm generally has a much more favourable meaning – 'ardent zeal for an object or cause'. The good teacher is an enthusiast, and he inculcates enthusiasm in his pupils. Yet the danger remains. Ardent zeal allied to truth is valuable, but allied to error it may do great harm. Unfortunately some of those most enthusiastic about our environment sometimes stray from the truth, and then I believe, they may do great harm both to their cause and to their pupils.

I must admit that it is not easy for the layman to disentangle the truth about our environments from the erroneous views often promulgated by those who should know better. For instance, there is the widely-held view that pollution is a comparatively new problem, and that pollution is getting worse and worse with each succeeding year. This opinion is expressed by the media – newspapers, radio and television – and also by scientists and teachers, including somes well-known university professors. Yet although pollution is indeed a serious problem, it can be shown that in most industrial countries many of its worst abuses have been greatly abated in recent years, and that most urban dwellers breathe cleaner air than did their parents and grandparents. There are still serious cases, some new industrial developments could have widespread harmful effects, the need for vigilance is obvious – but erroneous statements about our surroundings, statements which can be shown so easily to be wrong by observation of what is there for all to see, may do much to prevent any further improvement from taking place.

It is perhaps possible to forgive the media for their approach to the subject. The truth is generally much less exciting than fiction. A headline stating 'City's air slightly less dirty' is less likely to sell a newspaper than one which shrieks 'A thousand citizens choke to death', even if the details of this holocaust may prove difficult to establish. Unfortunately we all enjoy the sensational story

However, the main danger comes from the bogus expert. In the environmental field we have many painstaking and conscientious ecologists who are really trying to study the situation and to do all they can to improve it. At the same time we have a group of publicists, a few of whom do indeed have a proper scientific background, but the group is mostly recruited from the ranks of other disciplines (or lack of disciplines). In several countries these people are spoken of as 'The ecologists'. Now I do not deny that many of them are examples of enthusiasts who wish to make the world a better and a cleaner place. But because so much of what they tell us is false, they generally do more harm than good.

A worse danger arises from statements made by those who have a deserved reputation for their knowledge in some other field, but who appear to lose their critical faculties when faced with an environmental problem. The situation is complicated because we all, expert and non-expert alike, have our duties and responsibilities as citizens. The important thing is that those in authority, and those occupying posts which give them some scientific or academic standing, should make it clear when they are speaking as experts, and when they are simply concerned, non-expert citizens.

Every teacher is a person set in authority, an expert among non-experts, and this remains true even in schools which adopt the most non-authoritarian methods of instruction. The teacher's main difficulty is generally in deciding, particularly in some new field, who to believe and who to ignore. In fact none of us is a true polymath, expert in a great range of subjects. We can only speak with real authority, and from personal experience, in some quite narrow field of knowledge. We have to learn to identify the expert.

Although almost every major advance in science has been a result of the discovery that some widely held belief is untrue, we must nevertheless accept the somewhat unexciting view that the majority of orthodox and established opinions in our subject are, at least approximately, correct. We must examine carefully the credentials of those who express other views, and we should not deviate widely from generally held views without looking at the evidence very critically. This is something of a council of perfection, for few of us are even able to weigh up the evidence in many subjects, and this brings us to realise how we in fact form our opinions. We tend to accept the views of those who impress us most, by their ability, their honesty, or by their attractive personality. But I can give you one useful tip in evaluating those who are concerned with environmental problems. Take care to discover what they say about some problem, no matter how trivial, about which you yourself have some practical experience. If their views on this are sound, then, though you should not suspend your critical judgement, you may assume that there may be something in what they say. If you detect them in minor errors, you should be very suspicious of their views on more important matters. The great advantage of the environment as a subject is that we can all make at least some observations to check the opinions of the 'experts'.

There are obviously many environmental problems whose study may have considerable educational value. Some of these are in the field of pollution. First, they allow accurate observations to be made and recorded. Secondly, the interpretation of these observations can be discussed and evaluated. The third advantage of such work is that it can be related to real problems, which are of obvious importance to the individual and to the society in which he lives. At this point I would like to discuss two investigations with which I have been involved in which children tried to study the effects of different types of pollution.

Some four years ago, the Advisory Centre for Education in Cambridge, U.K., and the London newspaper, *The Sunday Times*, launched its first project to encourage children to study water pollution. A simple kit was devised to make elementary measurements of various substances in fresh water, but the most important feature of the project was the identification of a series of 'indicator' species of invertebrate animals which could be related to different degrees of water quality. Thus it was suggested that if mayfly and stonefly larvae were found, the water could be classified as very clean. The next grade contained caddis larvae and freshwater shrimps. Rather more pollution supported water lice and bloodworms, and the fourth grade such resistant

creatures as sludge worms and rat-tailed maggots. The most polluted water contained no recognisable animal life. Five grades of water quality were thus categorized by the possible presence of these different invertebrates; a check on the results could be made by noting the type of fish present.

The first advertisement of this project was at the beginning of the schools' summer holidays, and children were asked to make their observations in a week in August, well before the beginning of the next school term. Over ten thousand kits were bought, and over 80 per cent of the purchasers completed the exercise. The children were asked to survey one stretch of stream or river, but most did much more. Some cycled miles and studied long stretches of rivers, and sent in detailed reports and maps of their results. We were impressed by the enthusiasm of the children, and by the care with which they made their observations. Incidentally we were surprised by the age distribution of the participants – most were between 9 and 13 years, very few over 15. Some very young children of 7 and 8 made some good observations, and those we checked had mostly worked unaided by adults. In my opinion the project proved a great success. It could hardly be expected to produce new results of major scientific importance, but it did make possible the drawing of a more detailed map of water quality than had previously existed. It did teach the children how to recognise a real phenomenon, which was the effect of man's activities on the type of invertebrate animal living in the water. Many volunteered the information that they had located small local sources of pollution entering rivers, and that they could distinguish the clean-water fauna above the source and the foul-water fauna below. Some even persuaded local polluters to mend their ways, by demonstrating to them just what their activities had achieved.

A year later an air pollution survey was launched in a similar manner. A kit was devised, relating different lichens to different degrees of air pollution. An even greater number of kits – over twelve thousand – was quickly distributed. Again some very good records were returned, and a detailed map of lichens and of what was probably a good estimate of sulphur dioxide levels in the atmosphere was produced. However, there were various differences in the response in the two surveys. As I have already mentioned, we had a response of over 80 per cent response for the water pollution exercise, but for the air pollution the returns were only in the region of 10 per cent. I am unable to explain this completely. It might seem that children are more attracted to mucking about in water, even filthy and smelly water, and that wriggling animals are more inspiring than the most beautiful lichens!

Another point relating to these surveys concerns the interpretation of the results. Water pollution is a very real phenomenon, and the work clearly demonstrated how the environment was being damaged or improved by pollution and its control. However, the significance of the lichen work was less simple to demonstrate. When I prepared a factual statement about the survey for a newspaper, this was rejected in favour of a journalist's account of the 'Mucky air of Britain'. Now it was clear that in many areas where foliose lichens were absent, probably because there was too high a level of sulphur dioxide, there were few other signs of pollution. In fact we know that in areas of the United Kingdom where soils are sulphur deficient, a degree of this type of 'air pollution' is beneficial to grass and some arable crops. My general impression was that, as an exercise, water pollution is excellent and, without a great deal more explanation, air pollution is much less valuable.

Incidentally, I cannot resist mentioning one other difference between the surveys, which may have influenced the number of forms filled in and returned. That on water pollution almost completely bypassed the schools. We did find that a few keen teachers who lived near their schools helped their children in the holidays with work of this sort, but the vast majority of children sent for the kits of their own accord, and returned the results without showing them to any teachers. This caused complaints from some schools, and as a result literature about the air pollution scheme was sent to many teachers direct, at the same time that the project was advertised (and on this occasion, the advertisements appeared before the end of the school term). We know that

many teachers discussed the work with their pupils, and that in some schools it was made into a class exercise. It is difficult to avoid the depressing conclusion that, by bringing in the schools, we may have done something to reduce the enthusiasm of the pupils.

But I think that the important lesson to be learned from the air pollution exercise is that too much must not be claimed for the results of such investigations. If we give children the idea that, by studying a significant problem, their results will inevitably have a considerable impact on the community, this will usually lead to disillusion and disappointment. Even established research workers are sometimes upset when they realise how profoundly unimportant to mankind their investigations really are. But where environmental studies can truly be shown to relate to real problems, we are at least on the way to producing informed citizens.

Incidentally, when we speak of air pollution, we should realise that there is one problem which is at least one degree of magnitude greater than any other commonly encountered, and this is the self-inflicted air pollution of tobacco smoking. Even the non-smoker is exposed to something more serious than the air of our dirtiest city when he sits next to a smoker.

Now to consider my second topic – food, nutrition and the world's food resources. This is obviously a biological problem. Unless we all get enough of the right food to eat, our health, efficiency and ultimately our survival is affected. We know that in many countries there is just not enough food for the needs of the population, that undernourishment is common and that many deaths from starvation occur every year. Here are many problems which must be included in the biological curriculum.

Yet even more nonsense is spoken and written about food than about the environment. I sometimes think that the way the facts – and they *are* facts – about the science of nutrition are generally taught has done more harm than good. Thus we learn that there are substances such as protein and vitamins which are essential parts of a healthy diet. If we eat too little of them, we become ill. However, few people seem to realise that 'enough is enough'. Because some protein is necessary for health, they believe that the more protein they eat, the healthier they will be. Even governments, recording a rise in meat protein in their citizen's diet, say that 'the diet has improved'. In fact it is difficult to produce a diet, even a completely vegetarian diet, that does not contain sufficient protein. The only easy way to produce protein deficiency is to give too much sugar – and some children and old people do suffer from this cause, as the sugar replaces cereals which are relatively good sources of protein.

The same fallacies apply to vitamins. Foods are described as 'rich in vitamins' and therefore, presumably, likely to promote health. Unfortunately, in many countries it is the more educated citizens who are most convinced of this. They do not realize that once an individual has ingested the minimum requirement of these essential foods, any more is wasted, except that it may make the diet more interesting and more enjoyable. The trouble is that overindulgence in these comparatively scarce substances by the rich nations exacerbates the shortage in the poorer regions. Malnutrition is indeed common in all countries, but the cause is greed and overeating in one part of the world, and the shortage of essential food in another.

The food shortages in our poorer countries are attributed to the uncontrolled growth in population. This is only true to a limited extent. Population growth is indeed a serious problem, and a biological problem to be included in the syllabus. It is obvious that if population growth continues at the present rate in many countries, there will soon be far more people than the world can support. But that situation has not yet been reached, and food is not, at present, the limiting factor. If we had an effective world government, it could distribute the food produced today to ensure a healthy diet for at least twice the present world population.

The apparent world food shortage is caused by several factors. First, uncontrolled pests in crops and food stores take a heavy toll, perhaps as much as 25 per cent of all that is grown. Secondly, the waste in the kitchen and dining room of the food bought by the citizens of the wealthy nations is almost as great. Thirdly, those who overeat – and so damage their health – waste a considerable amount more. But the greatest waste of all is caused by feeding food that

could be eaten by man to livestock in intensive units in order to produce the large amount of animal protein which many of us, quite wrongly, believe is necessary for our proper nutrition. Few of us realise how wasteful this is. In Britain we feed more grain to livestock than we eat ourselves; between 92 and 99 per cent of this is simply wasted.

This statement may seem to need justification, for many of you will have been told that, for instance with intensively reared broiler chickens, a conversion ration of two to one may be obtained. This means that two kilogrammes of food fed to the chickens enables them to make a live weight gain of one kilogramme, a very creditable performance. What is not realized however, is that the food is a dry, high protein ration, containing fish meal, soya, maize and added minerals and vitamins. Though somewhat unpalatable, it would make an excellent human diet. Two kilogrammes of this makes one kilogramme of chicken. But when the chicken is prepared for the table, half (skin, etc.) is thrown away, and of the rest, two thirds is water. So the real conversion ratio is twelve to one, not two to one. Intensively reared pigs and bullocks are even less 'efficient'. Only when there is a world surplus of grain and soya beans, is it reasonable to feed this to animals, to produce meat that is eaten for pleasure, and not for necessity, by the more fortunate.

These are some of the truths that must be included in any course on food and population. They may be less exciting than reports of famine, agricultural desolation and inevitable mass starvation, but they may also help our pupils to redress some of the mistakes which have led to our present situation.

In conclusion, I wish once more to stress the grave responsibility of all those who teach biology, particularly where this is concerned with practical problems. They probably feel very strongly about the abuses inflicted on that environment by their fellow humans, by industry and by civilization. They probably feel very strongly about starvation and malnutrition in developing countries. These are things about which they should teach, but they are also subjects in which the truth may be difficult to disentangle from the propaganda arising from all sides. If they can show their pupils how to distinguish truth from biased propaganda they will have made a real and lasting contribution to their education for life in the twenty-first century.

The future of biology

by T. Gustavsson

It was perhaps unwise of me to accept an invitation to talk about the future of biology. We know too little about the future, and even if I were to restrict myself to some practical recommendations, the topic would be complex and could be approached from many angles.

I could for instance approach it from an educational point of view. Which parts of the enormous accumulation of rather specialized knowledge should we hand on to our students who are responsible for the future of biology? Do we give them the impression that we know more than we do? Do we give them the impression that we will soon have solved the problem of cancer, that we will soon be able to correct genetical diseases or schizophrenia, or carry out organ transplantations, or control and protect the ecosystem?

We could also discuss the topic from an economic or political point of view. Has biological research or basic science in general any place in a starving world faced with an explosive development of the population? Does biology involve a risk that, by working out methods for so-called genetic engineering, we may endanger human society? Would it not be wiser to restrict ourselves to a few specialized topics of immediate practical importance such as the biological control of pests, the treatment of trachoma, the control of pollution and the improvement of deserts so that we might live in a happier and wiser world? Would it not be better to leave more academic problems such as the evolution of molluscs, the sensory mechanisms of water spiders, the formation of mitochondria and the problem of integration in the nervous system to future generations? Or is it desirable – as I believe, and as I hope you believe – not to confine ourselves to attacking problems of immediate practical relevance, but to attempt to deal with every aspect of biology.

But I will leave educational, economic and political problems aside and, in spite of all my hesitation, I will restrict myself to the future of biology as a natural science, studying the nature of life and living creatures at every level of organization. I will deal with its internal structure. As it is difficult to talk about the future I will talk about some general trends in the past and present and then try to extrapolate into the future, or at least define some important conditions for a healthy, harmonious development of the science of life. I will paint a picture in black and white and make a lot of educational simplifications, and what I say may not even be true. You may well be exasperated and anxious to get rid of me before I have finished. Let me say straight away that I look upon the problems as a developmental biologist who has little understanding of the superiority of this or that approach, and who dislikes barriers between different biological disciplines. Men of my age, that is those in their late fifties, have witnessed a tremendous development in biology, in particular in the field of biochemistry, or more precisely molecular biology. Already I have made an over-simplification.

We have seen many colleagues leave the organismial level and enter the world of molecules. There, all the secrets of biology would be solved, they thought, and progress in that field has indeed been impressive. As a young student, I was amazed by the intricacy of the steps of glycolysis, which had recently been worked out. The reason for my interest in metabolic questions was the so-called metabolic gradients in the egg that appeared to be important for the developmental process, but the metabolic machinery itself soon attracted me. I also listened to discussions about the Krebs cycle that at first was considered by many to be an intellectual joke. The work went

on, maps of various complicated pathways now cover the walls of many laboratories and are very impressive.

The processes of oxidative phosphorylation and photosynthesis were also elucidated in much detail, but there were gaps in our knowledge which were difficult to attack. Unfortunately, these were the most important ones. However, during this period the biochemists began to realize that spatial orientation of molecules plays a fundamental role. A higher level of organization was therefore accepted. The idea that metabolic events could be reconstructed by mixing purified enzymes, co-factors and metabolites was accepted with respect to glycolysis, but not in many other cases. Our failure to crack the secrets of oxidative phosphorylation and photosynthesis reflects this. The biochemists therefore begun to study biological membranes, such as those found in mitochondria, the endoplasmic reticulum and the cell surface. New tools and new concepts were introduced. And we now begin to get a vague idea about the organization of some cell structures, how enzymes after attachment to the membranes change their activities and are able to interact in an appropriate way.

Thus, many biologists left the organismal level for molecules but had to return to a more complicated level and this is encouraging. But at the same time I have the feeling that the need for chemical and physical training grows stronger and I sometimes think that future problems at this level will not be solved by the old biologists who once left the organism for molecules. The biophysicists have entered the scene.

We can follow a similar development in the study of proteins and nucleic acids. When I was a student, the role of nucleic acid chemistry was intensively discussed among all biologists. Caspersson and Brachet and others had produced evidence that nucleic acids might represent the genetic material and play some role in protein synthesis, but nucleic acid chemistry was a mess and progress was limited to some elementary statements and guesses. Protein chemistry was also a mess and there were a few people who were not even convinced that proteins were polypeptides.

Both fields have undergone a tremendous development. The experiments of Astbury were a shock, but it has been argued they may have come too early to have a real impact. However, after a period of brilliant work by thousands of biochemists and cell biologists, the so-called genetic code was born. We learned that the sequences in DNA determine the amino acid sequences in the polypeptide chains which, as they are linked together, automatically fold up into intricate three-dimensional structures. Most important, too, is the finding that these structures may undergo conformational changes which are reflected by changes in enzymatic activity and that much of the intricate regulation of many life processes, such as some steps in formation of the genetic material itself, could be explained on the basis of conformational changes. What a biochemical triumph!

However, the details of regulation of protein formation are still not known and here also our ignorance is due to lack of sufficient knowledge about structural organization, in this case of the ribosomes. Once again, the biochemists had to return to a higher level of organization, and once again one has the feeling that there is little place for the old biologists; enormous biochemical and physical knowledge is required.

Some of the main results of molecular biology are known to every school child, but the more recent results concerning regulatory processes are so intricate and so much lack the appeal of the genetic code, that they are mainly discussed in a rather restricted circle of specialists using a very difficult language. Here is another reason for dismissing the old biologists.

The biochemists have invaded still higher levels of organization and have even begun to work with intact bacteria! Their results have had an enormous impact on other branches of biology far outside biochemistry. Endocrinology has undergone a tremendous development since the elucidation of the role of membrane-bound adenyl-cyclases which, under the influence of specific hormones attached to receptor molecules at the cell surface, change their activity and give rise to cyclic AMP, which then works as an activator of various enzymes. The isolation of cholinergic

receptors, currently being pursued, and the discovery that cyclic AMP has a sister, cyclic GMP, and that the two to some extent mediate opposed neurotransmitter effects is one indication of the enormous impact which molecular biology has had on neurobiology. I might also mention the dopamine story in relation to Parkinsons disease. No doubt biochemical achievement of this kind will stimulate various biological fields and provide the endocrinologists, neurobiologists and others with new tools. This is an optimistic outlook for the future of biology.

But quite as often the biochemical achievements may have an opposite effect. As a developmental biologist I must confess that I have sometimes considered giving up the problem of differentiation, obsessed by the feeling that this field is only open to biochemists who are capable of purifying and defining some regulatory proteins attached to the genetic material. The story of Monod and Jacob and the work on the role of acidic proteins as policemen that displace basic proteins from DNA and thereby induce its transcriptional activity is intellectually satisfying, but it does not encourage a traditional biologist to continue along the same lines. Such biologists certainly did some fundamental work in the thirties, on the principles of embryonic induction and on the interaction between rather obscure gradients in the egg, for example, but they may be incapable of carrying on their analyses at the molecular level. Like many other biologists, they have a feeling of alienation, of being obsolete and superflous. If they tried to do some biochemical work and were successful they would still have the feeling of having left the organism behind.

There are also technical reasons for this feeling of alienation. A pre-requisite for this enormous biological progress was a rapid invention and refinement of scientific tools. The development of Tswett's clumsy chromatographic column into the modern gas-chromatography or thin layer chromatographic plates and the amino acid sequence analyser has been impressive. We can now separate the pheromones from a few glands of a bee and quickly determine the amino acid sequence on an almost invisible sample of protein. Some of these tools are easy for the layman to handle and this is a reason for optimism, but in the majority of cases the old biologist has little skill in using these tools. He needs a well-trained engineer by his side.

One exception is, no doubt, the transmission and scanning microscopes which are used by, a great many traditional biologists gather. But in order to go deeper into the problems, a completely new type of knowledge is often required, and this must be supplied by the physicist and technologist.

I could continue my biochemical and bio-physical appasionata indefinitely and I realize that I have forgotten the tremendous development in immunology, the action-myosin interaction, the rapid progress in electrobiology and so on, but this does not change the picture. The molecular biologist and biophysicist have laid completely new foundations for biology, in some cases their concepts, molecules and tools can be of great use for the so-called old biologist, but quite as often the latter feels incompetent to carry the analysis further and even that he would lose his identity and basic interests if he tried. What identity? Which problems? I will come back to that later. The molecular biologists and biophysicists have also invaded other branches of biology and begun to study more complex structures such as membranes and fibrous elements, and the biologist of the old school may ask himself if he should give up biology completely. The molecular biologist can do the work. I must underline that what I say is a crude caricature in black and white. I will now try to situate the molecular biologist in his place.

Is the future of biology no more than the future of molecular biology? Does it depend on an increasing specialization on the part of scientists who only study tiny fractions of so-called living matter? Does it depend on the development of more and more refined and intricate laboratory equipment that soon will be so expensive that it must be mainly concentrated in international research institutes? Will biology more and more be a question of purifying molecules and fitting them together again? Will biology more and more be a science concerned with *Eschericia coli*, the liver of the white rat and possibly *Chlorella*? Will there be any need for other creatures? Is ultrastructural research the endpoint of scientific biology? Is everything above the

ultrastructural level uninteresting? No! I used to say to my colleagues who decapitate white rats and homogenize them in order to separate some particles: 'But you are throwing away the best part of the animal! The head with its brain and its billions of synapses and pathways, and the feet and toes. Even the tail represents a tremendous problem! You may reconstruct a ribosome by mixing together a number of molecules, but you cannot produce a brain or a toe in that way.'

Yes, biology is also about organization and functions far above the membrane level. We have toes and fingers. We have brains which are organized in a marvellous way and which can produce secretions such as *La Divina Commedia*, Beethoven's string quartets, and mathematics. It is such an organization that enables bees to communicate, birds to listen to signals telling them to migrate or to find their way by the stars. It is this organization that allows bats to find their food in the dark. This dynamic organization is also found at the supra-organismic level. It is responsible for the remarkable fluctuations or sometimes stability in animal populations, and the whole ecosystem involves giant questions of dynamic organization. The macro- and micro-evolution refer to the modes of change of this organization. Developmental biology is the story of the creation of the organism from the simple egg.

Are there then a lot of dynamic structures that are not directly a consequence of molecular organization? Of course they are. I am no antireductionist, but the molecular biologist will not reach the answer in the way he works, and solely on the basis of his own concepts and sophisticated instrumentation.

Let us now turn to the future. It is interesting to see a great number of molecular biologists taking the long step from the molecular organization to the complexity of the organism, thereby joining the so-called old biologist who has always dwelt there and studied this complexity by his own methods. A counter current in biology far past the membrane level! Sometimes these steps are not so long. Molicular biologists use their knowledge to elucidate the structure of the chromosome of higher organisms, which is something quite different from the *E.coli* chromosome, but in doing this they will probably realize that they must learn a lot from the old-fashioned regulation of the gene activity and the process of evolution. They will realize that the three-dimensional structure of the chromosomes probably plays an essential role in gene regulation and they may also find that evolution is not just a question of mutation of individual genes and amino acid substitutions. The enormous and often abrupt diversification in many groups is – this opinion can be defended – based on changes at a level that in general molecular biologists have so far overlooked.

A particularly long step is taken, when the molecular biologists begin to try to find the secrets of morphogenesis at tissue and organismal level. In fact, many molecular biologists realize that the fitting together of amino acids into proteins, or molecules into membranes, is not the whole story. They realize that the fitting together of cells into complex structures, into brains, hands and whole organisms is a terrific, provocative problem. Hence they join the old traditional biologist – another instance of this interesting counter current in biology. The organism is allowed to exist and to be investigated in all its complexity.

Sidney Brenner's isolation of various mutant nematodes with various abnormalities in behaviour is an example. He makes an ultrastructural mapping of the neurones and their connections to elucidate the genetic control of morphogenesis of the nervour system and hence the genetic control of behaviour. Crick's interest in the nature and mode of operation of the old-fashioned embryonic gradients and the more recent concept of positional information are another example. One could also say that the activities summarized as neurobiology are a reflexion of this increased interest in the complexity of the organism among the molecular biologists who there work side-by-side with electrophysiologists, ultrastructure specialists, anatomists, psychologists, and comparative physiologists. An old-fashioned student of the cellular mechanisms of gastrulation and morphogenetic events at later stages in the sea urchin finds himself in good company with a lot of famous molecular biologists. I remember with amusement that some fifteen years ago I tried to explain to a colleague what I was doing. I got the dry answer: 'You are superficial and old-

fashioned, aren't you? Would it not be wiser to work with the protein synthesis of the larva and not look at shapes – they are already known!' As if the problems I dealt with did not also involve questions about molecular processes that trigger and control the morphogenetic cell movements – which, moreover, were little known all that time.

The breaking of barriers between molecular biology and the biology of higher levels of organization is indeed, as I see it, one of the best promises for the future. We have learned a lot from the molecular biologists and can use the knowledge without giving up our problems; and they join us and, I hope, learn a lot from us and find our problems, approaches and concepts respectable and important. Another trend in biology, which has a close relation to the general increase in interest in complexity, is that many mathematicians and theorists are beginning to orient themselves towards biology. An expression of this is the foundation some fifteen years ago of the important *Journal of Theoretical Biology*. Theoretical or mathematical biology has been looked upon with suspicion by many biologists in the past and there will always be a lot of biologists who prefer observations and experiments on biological objects, but theoretical modelling can reveal possibilities worthy of consideration. Very often we may learn from such work that we are looking in the wrong direction, that we are collecting useless information and asking the wrong questions. I am not a theoretical biologist myself – unfortunately, there are many defects in my scientific training – and I can therefore not speak passionately enough about the achievements of theoretical biology. You may, however, look for yourselves at the July issue of *Theoretical Biology* (1975) and read about a model generating the complicated pattern of skeletal elements in the embryonic chicken limb, a mechanism based on assumptions of rather simple localized cell-to-cell-interactions.

Another trend in biology is that we are beginning to realize that we should utilize and study the *whole* animal or plant kingdom – many individual biologists, all so-called old-fashioned ones, have done this without asking for permission. One reason for this, and not the only one, is that experiments with a few species, no matter how intelligent and intricate the experiments may be, cannot reveal all the secrets. By using fishes, which have been the subject of an enormous series of experiments, we can learn a lot of fundamental things, about the autonomic nervous system for example, but they are not suitable material for solving other problems.

The trend towards more complex levels of organization is also reflected in the rapid development of the biology of the supra-organismal level, such as population biology and ecology. Population biology is a field I am not too familiar with, but it will certainly play an important role in the future and shed light on such problems as the cause of the tremendous fluctuations in population densities that have been recorded.

Ecology is rather a young science. When I was a student there was little teaching about ecology in Sweden except in limnology and plant sociology. It is still to some extent in a descriptive phase. One sometimes wonders if the correct data are being collected. The healthy development of ecology will depend, I think, on the same factors that are required in other branches of biology, i.e. breaking down barriers between different levels of organization and other branches of biology. Ecologists should learn more about the functions of the living creatures that make up the biological component of the ecosystem. We should realize that ecology is physiology at a supraorganismal level, and just as a general physiologist goes down to cells and molecules, so the ecologist has to consider the functions of the single species. The breaking down of the barriers to theoretical biology has, on the other hand, advanced rather fast, not least through Odum's ideas about the energy flow through the ecosystem, which one day may help us to get a total model of this dynamic structure.

But now I am being guilty of the same sin as some molecular biologists when discussing other biological branches! The healthy development of a science does not only depend on breaking down barriers. Every science should also be allowed to develop according to its own dynamics. Ecology, more or less closed within itself, has already formulated many problems and reached fundamental results, such as certain laws determining the stability of the ecosystem.

As a general summary, I would say that biology represents a house with many floors, the world of molecules at the bottom, the ecosystem at the top and the organismal and cell level in between. Each floor has many rooms, often with rather narrow doors. One may defend the statement that, in the public mind, the activity has been particularly successful down at the bottom and up at the top. People on the middle floor have had the advantage of utilizing many of the results from the bottom floor. But very often they are afraid to go too deep into molecular biology, partly because they feel unable to work with such problems, partly because they have the feeling that by going down they would loose their identity; they would drop the global aspect of the problem, an aspect they consider essential. Sometimes they feel very frustrated because the molecular biologists appear to try to invade their own floor. Some of these, just a few, are also rather nasty schoolmasters who tell the old biologist that their problems are obsolete. An interesting trend, however, is that some molecular biologists take a long jump up into the higher floors, bringing a lot of know-how and enthusiasm, but at the same time demonstrating respect for the organismal problems and readiness to accept new methods and new concepts. A similar fruitful development in ecology is underway, and the breaking down of the barriers with regard to mathematical biology is also rapidly taking place.

We are beginning vaguely to realize that every section of biology should be allowed to develop according to its own intrinsic structure. Breaking down barriers is an expression of tolerance. Accepting the uniqueness of every branch in biology is also a question of tolerance. Apparently the future of biology will be a question of tolerance. Thus the future of biology becomes a question of ethics. If we realize this I think that the development of biology could be brilliant. If we do not, biology will be characterized by increasing specialization, friction and a feeling of alienation in some branches. This will lead to a lack of progress as the analysis of the complexity of the organism will be retarded.

Trends in the purposes and objectives of biological education

TERMS USED TO DENOTE THE PURPOSES AND OBJECTIVES OF EDUCATION

There is no terminology to denote the many shades of meaning in connection with the purposes and objectives of education. Two main groups of terms, however, are commonly employed:

Group A. Terms which are connected with the broader purposes of education, viz. *purposes, ends, goals, aims, general objectives.* These are frequently concerned with the long-term targets of education, i.e. the behaviour of the individual person many years after the learning experience is over (skill in drawing conclusions from data; cultivation of an attitude of respect and love for natural objects, etc.) They tend to be much the same for a wide variety of subjects in the curriculum.

Group B. Terms which are connected with the more specific objectives of education, as in the case of a given subject in the curriculum, such as biology. They are commonly denoted as *specific objectives* or *objectives* or *outcomes*. They are usually concerned with long-term targets as well as with medium-term targets (such as skill in drawing graphs or passing examinations) and especially with short-term targets (such as knowing the steps of a biochemical cycle).

INTRODUCTORY PARTS OF A STATEMENT OF PURPOSES AND OBJECTIVES

The target population

In dealing with a statement of the purposes and objectives of biological education, it is important to know to whom they are to apply. Thus the purposes and objectives in the biological education of senior school students are not likely to be precisely the same as those for a selected group of university students, or for the general public, or even for junior school pupils. The chapter on biological education for the general public contains a list of aims which are general enough to apply to a wide range of school curricula (table 1).

Table 1. Aims of biological education in schools

1. Fostering and sustaining interest in learning the scientific process and sustaining interest in a comprehension of the causes of events.
2. Training in the skills and attitudes of the scientific method.
3. Imparting factual knowledge.
4. Imparting motor skills.
5. Stimulating pupils to maintain a science component in higher education.
6. Stimulating application of the principles and skills of science to relevant areas outside science.
7. Promoting understanding of science in the cultural life of the individual and society, and thereby promoting the breakdown of the so-called two cultures (arts-based and science-based).
8. Training for specific careers in biology.

The broad objectives of biological education are the same at all levels of education, namely to assist the learner to become a better individual and a better citizen. In order to avoid the necessity for an unduly long statement of objectives it would be helpful to choose a narrower target population. Let us assume that this consists of students aged about 15 years and studying at secondary level in a school system. Let us also assume that the biology course receives something of the order of 150 hours of teaching time in the school schedule and that a laboratory and books are available.

General objectives

'The course in general biology is meant to contribute to the development of the student into a happy and useful being'.
This is meant to show the user of the course that the philosophy behind the course places a value on individual happiness as well as on co-operative behaviour. A similar statement, paraphrased from the companion volume on chemistry (Frazer, 1975) shows a threefold aim for biology courses at secondary or tertiary level:

1. to prepare students for professional careers;
2. to contribute to a general education (i.e. education for a full and useful life in contemporary society) using biology as a vehicle.
3. to inform future citizens of the nature and role of biology in everyday life.

At secondary level, the order of importance is 3>2>1, whereas at tertiary level this order is reversed.

It may be mentioned in passing that purposes are sometimes stated only in regard to usefulness (and not in regard to individual development). For example: 'The present purposes of higher education are to produce individuals, expert in various specialities, to maintain and develop the economy and advance knowledge in an increasing number of fields' (Beard, 1968).

What happens if the aim of individual happiness is in conflict with the aim of useful co-operative behaviour? For example, the aim of developing co-operative behaviour may involve the learner in manual labour (cultivating a garden plot) while the aim of developing individual happiness may have to take account of the fact that some individuals hate manual labour. The solution of such conflicts should be left to a later point in the curriculum-making process, namely, when considering methods to be used in learning and teaching; what is to be noted now is that there may be hidden conflicts between objectives, that these conflicts are recognizable and that compromises are inevitable.

It must be admitted that it is unusual for a statement of purposes and objectives to stipulate the ends of the course in the above manner. This is because such a statement sounds so trite as to be unnecessary; it applies to all education and not specifically to biological education; and it is vague and can lead to endless hair-splitting argument which the pragmatic curriculum-maker may consider an unnecessary waste of time. Exactly similar remarks apply to such aims as the development of the student's unique personality, his adaptability, awareness, zest for life and work, and reasonableness in dealing with other people and their work.

Priorities among objectives

It would be helpful to the users of a curriculum if priorities were recognized and listed in the statement of the curriculum's objectives.

In order to indicate priorities a rating scale could be used as shown in table 2.

Table 2. A rating scale for objectives

I	Objectives which are to be pursued intensively and in depth.
II	Objectives which are to be pursued in depth (but not intensively).
III	Objectives which are to be pursued as an essential part of the course (but not in depth).
IV	Objectives which are to be pursued as the opportunity arises.
V	Objectives which are postulated but rarely pursued because of a variety of constraints such as lack of time, lack of materials, and lack of maturity of the students.

Another way of indicating priorities is to make statements such as the following:
'The course lays particular stress upon:

- an all-round knowledge of biology;
- the use of the experimental method in solving biological problems.

This is vaguer but at least indicates fairly clearly that the course would not leave out a topic such as genetics or evolution or reproduction, and that it would not treat science merely as a body of sound knowledge.

Still another way is to set down the approximate number of hours which are to be spent on each topic during the teaching of the course.

In countries with public examination systems, the examination papers give implicit clues to the students as to what the examiners consider to be the examinable priorities of learning. Examinable priorities may be overshadow other priorities which are valued by the examiners (e.g. enjoyment of biological literature) but which are non-examinable at present.

OBJECTIVES

It is convenient to classify objectives into the three well-recognized domains of human experience, i.e. cognitive (knowledge), psychomotor (motor skills) and affective (feelings). It is accepted that all three domains are often involved together in acts of learning and that their separation, as below, in relation to biology learning is mainly a matter of convenience in stating the objectives. It is also to be noted that the will to do something (conative domain?) is not the same as knowing about it, knowing how to do it, and feeling like doing it. The specimen statement of objectives set out in table 3 is divided into six sections:

- the content of the knowledge to be learnt;
- the cognitive levels and national and human particularities which should be cultivated in learning the content;
- the aspects of social and applied biology which are to be taken into account in learning the content;
- the particular intellectual skills which are to be developed while learning the content;
- objectives in regard to psychomotor skills;
- affective objectives;

Table 3. Specific objectives of biological education at senior secondary school level.

	Priority Rating
1. *Knowledge* of the principles of:	
– the *classification* of the organisms (so as to show their unity and diversity);	III
– the *barrier* (tegument) between the organism and the external environment;	V
– the *input* of energy and materials into the organism;	III
– the *output* of energy and materials from the organism;	III
– the *transport* of materials within the organism;	III
– the *co-ordination* of functions within the organism;	III
– *movement* of organisms;	III
– *reproduction* in plants and animals;	III
– *development* in plants and animals;	III
– *inheritance* of biological characteristics;	III
– *organic evolution;*	II
– biological *populations, communities* and the *biosphere;*	III
– the *chemical* substances found in organisms;	III
– *balances* (including homeostasis) in organisms, populations, communities and the biosphere;	III
– the biological basis of animal *behaviour;*	III
– the *literature* resources of biology;	V
Note Various re-groupings of the items in the above list are possible.	
2. The knowledge described above is to be treated –	
– not only at the level of learning for recall but also for the higher levels of application, analysis, synthesis and evaluation*;	II
– so as also to exhibit the *processes* by which biological knowledge is obtained;	III
– so as to exhibit the tendency to *quantify* biological concepts;	V

*The terms used here are from the well-known taxonomy of educational objectives by Bloom and his colleagues. It is worth noting the following passage as an example of what one group of leading biology curriculum reformers felt about the taxonomy:

'Bloom's taxonomy was used only as a guide for formulating the Nuffield A-level Biology objectives. This decision was arrived at after careful investigation. Possibly the major lesson that was learned from it was that while it is possible to find biological (or scientific) examples to fit Bloom's categories, it is far more difficult, and in some cases

Table 3 continued

	Priority Rating
– so as to exhibit the process by which biological knowledge *changes;*	V
– so as to show the links between biology and other *basic sciences;*	IV
– with special reference to the flora and fauna of the country;	II
– with special reference to biological research studies which have been carried out in the country;	II
– with special reference to *man.*	III
3. The knowledge described above is to be used as a basis for learning the factual (objective) biological aspects of the following topics in social and applied biology:	
– Food and nutritional situation in the country	III
– World food situation	IV
– Health and sanitation	IV
– Climate, clothing and building in the country	V
– Environmental changes resulting from human activity*	III
– Population growth in the country	III
– World population growth	IV
– National development plans	IV
– Behaviour of human groups	V
– War and peace	V
– Artistic experience	V
4. The following intellectual skills are to be developed while acquiring the knowledge listed above:	
– Skill in reading biological data presented in the form of tables, bar diagrams and line graphs	II
– Skill in casting biological data into the form of tables, bar diagrams and line graphs	III
– Skill in summarizing the data in terms of arithmetical mean, range, and other parameters	V
– Habit of looking for data and other evidence in a book or paper	V
– Skill in drawing conclusions from data	III
– Skill in proposing hypotheses to explain the conclusions	III
– Skill in designing fact-finding surveys, and experiments to test a hypothesis	III
– Skill in using reference books in biology	V
– Skill in writing up the results of a survey or experiment in the manner customary in biological science	V

*Special attention should also be given to micro-environmental problems such as intensive farming, smoking, etc.

5. Objectives in regard to *psychomotor skills*	
– Ability to carry out surveys or experiments in relation to the knowledge described above, including the ability to construct simple apparatus for the experiments.	III
– Ability to use the hand lens and the compound microscope.	III

The above motor skills are to be developed at least to the level of guided response. A taxonomy for the psychomotor domain has been prepared by Simpson (1969); she recognizes six levels: perception, set, guided response, mechanism, automatic performance, and adaption.

impossible in any relevant sense, to fit the 'Bloom' categories to acceptable and recognizable student objectives of a biological education as we defined it. What is done depends on one's interpretation of priority. We considered it more important to accent "biological education" objectives rather than Bloom's taxonomy. The latter defines a hierarchy and priority of relationships which appeared to be of limited value in the specific context of A-level biology' (Kelly, 1972).

Table 3 continued

6. *Affective* objectives
   - The student should develop an attitude of love for living organisms and respect for the self-replenishing cycles of nature; and respect for the right to use or not use the stores of biologically-deprived material. IV
   - The learning of the knowledge listed above and the motor skills should be accompanied by an affective aura at least at the level of valuing learning. II

The taxonomy of the affective domain as described by Krathwohl *et al.* (1964) contains five main levels: receiving (attending), responding, valuing, organization, and characterization by a value or value complex.

The statement of objectives gives no indication of the sequence of topics in teaching the course. The Roman numeral placed after each objective indicates the weight to be given to the objective, according to the key given in table 2.

Other ways of classifying objectives

The National Assessment of Educational Progress (United States), in 1972 - 1973, used three 'primary' categories of educational objectives in science:
- to know the fundamental aspects of science;
- to understand and apply the fundamental aspects of science in a wide range of problem situations;
- to appreciate the content and processes of science, the consequences and limitations of science, and the personal and social relevance of science and technology in our society.

Each primary objective is divided into 'sub-objectives' and each sub-objective is further defined with descriptions of behaviours which are used to test the student's learning.

As an example of a deliberately brief statement of objectives, that of the Nuffield biology materials ('ordinary' level) could be cited:
- to develop and encourage an attitude of curiosity and enquiry.
- to develop a contemporary outlook on the subject.
- to develop an understanding of man as a living organism and his place in nature.
  The usefulness and social implications of biology in relation to man's everyday needs, e.g. food and public health.
  The profound influence of man's activities on other organisms.
  The way in which a study of biology enables man to interpret observations that he makes in everyday life. e.g. the distribution of plants and animals.
- to foster a realization of the variety of life and of underlying similarities among living things.
- to encourage a respect and feeling for all living things.
- to teach the art of planning scientific investigations, the formulation of questions, and the design of experiments (particularly the use of controls).
- to develop a critical approach to evidence.
- to develop the following ideas about biology as a part of human endeavour.
  Biology has been developing over many centuries: there are many unanswered questions about life; our ideas of life may change as new knowledge is obtained.
  Biological knowledge is the product of scientists working in many different parts of the world. Its pursuit is international.
  It is based not only on observation and experimentation but also on questioning, the formulation of hypotheses, testing of hypotheses, and, above all, on communication between people.
  Developments in chemistry, physics, and mathematics are helping us to make advances in biology.

Developed vs developing countries

If the purposes and objectives were essentially the same for both groups of countries, this is not to say that the content of the courses would be the same; the content could in fact be different for each country in view of the differences in the fauna and flora and the social and ecological problems facing different countries.

INFLUENCES THAT DETERMINE THE PURPOSES AND OBJECTIVES OF EDUCATION

The most important of the various influences which have decisive effects in selecting the purposes and objectives of education could be listed as follows:

Concern for development of the learner as an *individual.*
Concern for *priorities in the social system* of which the learner is a part.
Concern for the ethos of the particular *discipline* of study (subject).
Concern for *generalization about learning.*
Concern for the *teacher.*
Concern for putting available *technology* to use.
Concern for *religious beliefs.*
Concern for *cultural pressures.*
Concern for *commerce.*

In the ensuing sections examples will be given from contemporary biological education to illustrate these influences. In practice, of course, we should expect to find that for a given goal or objective – in biological education as in everyday life – there are usually more than one influence at work in prompting it. For instance, the objective of helping the learner to *learn* about reproductive processes in vertebrates may end its source in a concern for the development of the learner as a human being, a concern for a social priority such as the problem of human population growth, a concern for the discipline of biology where it seems wrong to neglect so important a biological phenomenon as reproduction in a biology course, and a concern for cultural pressures such as a lessening degree of puritanism in human relationships. Nevertheless, the decisive influence which determines the inclusion of a goal or objective is often more clear-cut.

PURPOSES AND OBJECTIVES FOR THE DEVELOPMENT OF THE LEARNER AS AN INDIVIDUAL

In Western societies, self-development tends to be rated higher than anything else. A survey carried out in 1973 in the United States by the National Commission on the Financing of Post-secondary Education showed that "self-development was the leading reason given by students for seeking education beyond high school. The second most important reason was employability" (*The Times Higher Education Supplement*, 7th February, 1975).

Individual cognitive domain

Thinking for oneself

All contemporary biology curricula tend to lay stress on the goal of independent thinking by the the learner. A variety of terms is used to denote various facets of thinking. These include:– *open-mindedness, inquiry, discovery, problem-solving, fluency, flexibility, insight, and originality.* Teaching materials prepared specially to serve this purpose include discussion units or more complex packages which include readings, projects, etc. Studies have sought to show that thinking performance is improved by the use of BSCS courses (Woodward), BSCS inquiry films

(Castelli, 1970), the BSCS 'Invitations to Enquiry' (Starr, 1970), and inductive vs deductive teaching (Egelston, 1973). Analyses of the concept of inquiry have been produced (Bingham, 1969), including one from Thailand *(Teaching by Inquiry)*, and a review of research on science teaching methods has appeared (Ramsey & Howe, 1969). Open-minded teachers are said to fare better than authoritarian teachers in regard to the practice of BSCS ideals (Jones & Blankenship, 1972).

Learning to learn

The aim here is to furnish the learner with the habit of learning on his own so that he may become a lifelong learner (the three L's which, as is sometimes remarked, should replace the conventional three R's). Attempts to achieve this aim in biology have included the use of student-structured material (Penick *et al.*, 1974) and individualized learning with BSCS materials (Fulton, 1970).

'Essential' knowledge

The aim, in T.H. Huxley's words, is to 'furnish them (the learners) with the most important portions of that immense capitalized experience of the human race which we call knowledge,.. the great and fundamental truths of Nature'. 'Scientific literacy' is more than mere scientific knowledge; it has been analysed into three components – facts, processes, and cultural impact (Klopfer, 1969). But knowledge of facts remains necessary for higher cognitive operations, even in elementary school biology. This is certainly not the same as viewing the learner as a mere vessel to be filled. Concern for this goal has recently given rise to biology curriculum materials for adult self-study *(Advanced General Education Program)*.

Integration of knowledge

Assuming that the division of knowledge into 'disciplines' or 'subjects' is arbitrary and a matter of convenience to teachers and scholars rather than to pupils, educators have advocated the aim of helping the pupil to recognize the unity of knowledge and the artificiality of its customary subdivisions. Practical outcomes of this integration viewpoint have taken several forms.

Integration within a framework of biology. The curriculum-developer arranged a course which is still called biology but which includes plenty of material from other disciplines including chemistry and physics. The BSCS *Human Sciences* for middle school is an example of this. Even the BSCS blue, green and yellow versions for grade 10 in United States, schools were permeated by this aim, especially since chemistry and physics came in grades 11 and 12 in the school system. In universities there have been efforts to get different departments to identify the subject matter which is common to them and to run joint courses on this common area (Apostel *et al.*, 1972). We may also note the current tendency in universities in England and Wales to shift away from single-subject (honours) degrees to those with two or more subjects. The chapter on university-level biology courses describes the course which is being developed in the University of Bath to integrate the teaching of biology around three basic themes (the spatial distribution of organisms, the flow of energy in ecosystems, and the gene as an element in the continuity of populations).

Biology integrated into general science. Biology disappears as a separate subject; its topics are incorporated along with those of chemistry, earth science, physics, etc., into general science. Many examples can be cited.

England: Nuffield Combined Science (grades 7 - 8);
Nuffield Secondary Science (for young school leavers);
Foundation science course of the Open University.
Scotland: Science for the 70's (grades 8 - 9) (Mee *et al.*, 1971);
Sri Lanka: Science (grades 6 - 9);

United States: Idea-centred lab science (I–CLS);
Two-year, three-year and four-year high school integrated science programmes;
Unified science approach K 1 - 12 (Showalter, 1968).

Individual person: affective domain

The aim of educating the feelings has received a high place in educational thought. Plutarch in memorable phase affirmed that a child's mind is 'not a vessel to be filled but a fire to be kindled'. Agricola (15th century) wrote: 'If there is anything that has a contradictory name, it is the school. The Greeks called it *schole,* which means *leisure, recreation;* and the Latins *ludus,* that is, *play.* But there is nothing further removed from recreation and play. 'William Godwin (c. 1800) used a biological metaphor in observing that 'the formal lessons of education pass over without ruffling a fibre of his heart; but his private contemplations cause his heart to leap, and his blood to boil.'

The aim of educating the feelings takes the form of objectives such as helping the pupil to develop and cultivate respect and love for living organisms and for books and learning. The chapter on curriculum evaluation observes that 'the aesthetic values of a tree, a flower, a bird, or of grass need to be included in developing environmental awareness. In some cultures, such as that of Japan, this has reached a state of high art; in others, it may not even be a consideration.' A plea for focussing attention upon the affective domain in biology has been made afresh (Kuhn, 1973). A list of affective objectives in biology and an account of its use in the classroom is given in Glass (1970). Measurement of affective objectives in biology students has been described (Selmes, 1973; Simpson, 1973; Skinner & Barcikowski, 1973). One of the mainstays of the recent enormous movement to produce self-instructional materials and modular courses is the aim of helping the student to *enjoy* learning by doing so at his own pace and according to his taste.[1] Yet another recent large-scale movement, 'outdoor education', has strong roots in the aim of enjoying learning. Words such as 'curriculum enrichment' by outdoor education carry the same intent. The principle of learning by 'discovery' methods has roots in the affective involvement of the pupil.[2] The phase 'meaningful' topics is laden with affective overtones. Another affective goal is a *sense of responsibility.* It is claimed that the practive of getting senior students to teach junior students in college develops a sense of responsibility in the students (Wise, 1968). *Self-reliance* is said to be one of the outcomes of self-instructional methods of education (Waskoskie, 1973). The strong belief of teachers in the value of providing actual *experience* for the pupils is full of the affective influence. Is this not one of the main reasons for doing field work with biology students, community work in biology (Sutcliffe, 1973) and 'the environmental classroom' (Hawkins & Vinton, 1973) and visits to aquaria, gardens, and zoos (Turkowski, 1972)? Field work takes a multitude of forms which have in common a desire to cultivate a feeling for nature: there are nature study centres (Hoban, 1973), out-of-school activities (including a side programme sponsored by Unesco) (Stevens, 1969), vacation courses for students (Perkins, 1973), long trips, and projects. Field trips are not necessarily superior to lectures in regard to knowledge and attitude outcomes in students (Brady, 1972).

The relationship between feelings and knowledge has been explored in a few studies. Strong

1. It must not be forgotten that that old educational device, the *book*, has always had this advantage of letting the learner learn at his own pace. Some educators have always allowed for the pupils' individuality. Pavlov, recalling with gratitude his secondary education in a theological seminary in Ryazan, Russia, (ca. 1860), wrote: "One could follow one's own intellectual inclinations, which was not the case, regretably so, in the notorious Tolstoy gymnasiums" (named after D. Tolstoy, a minister of education who made the gymnasiums into scholastic schools with hard discipline).

2. Rousseau's *Emile* "knows little but what he knows is really his own. His thoughts are not in his tongue but in his brain. Let him not be taught science, let him discover it."

feelings can improve the results in some situations (for example, teachers with strong feelings for experimental work were found to produce a higher performance on 'inquiry' skills in their students) (Driver, 1969), but they do not necessarily go with a high level if knowledge. The converse might even occur: feelings high, knowledge low (Schock, 1973). Students who loved biology in school may drop out of it in college. Strong feelings are far less important than cognitive activity for some areas of work, e.g. learning genetics.

PURPOSES AND OBJECTIVES CONNECTED WITH PRIORITIES IN THE SOCIAL SYSTEM OF WHICH THE LEARNER IS A PART

The piper calls the tune. When the piper who purveys education is an institution or a government, the tune that he calls will understandably reflect the interests of the institution or government. Even in the southeast Asian island utopia of Pala, the goal of education was 'to live as fully as human beings in harmony with the rest of life on this island at this latitude on the planet' (Aldous Huxley). In cruder formulations, the pupil is a piece of clay to be moulded into fine and useful shape. He must have knowledge of his own country and not only of the world at large (Unesco, 1969). The principles which he learns must where possible be illuminated with examples from his own environment. This is the objective behind curriculum materials which pay special attention to the country's own data, e.g. in Sri Lanka (Basnayake, 1974, and the use of common local plants in the learning of biology, e.g. in the Philippines *(Interaction of living things and their environment)* and Nigeria (Lawton, 1972). Secondary school students in the Arab region should learn about the efforts of biologists with special reference to the role of Arab scientists (ALECSO, 1973).

The applications of biology to society are of widespread interest to biological educators (Grobman, 1970). Professional courses should take the needs of society deeply into account The chapter on curriculum evaluation notes the view that courses must be 'issue-oriented, including such topics as reproduction, birth control, pollution, populations, aggression and other concerns of the citizenry'. There are curricula and examinations in social biology (e.g. A–level social biology). One of the aims of the Nuffield Advanced Biology curriculum is to train the student to 'evaluate the implications of biological knowledge for human society'. The most far-reaching current development of applied biology in school and college curricula has been in the field of ecology and environment. There are a great many courses, parts of courses, texts, kits, reviews, guides, conference proceedings, etc. devoted to these subjects. Some institutions are devoted entirely to them, e.g. Ecology College (Goodman, 1973) and the University of Wisconsin at Green Bay. These and other programmes include environmental research projects by students. Outdoor education is a huge enterprise. Conservation is an important facet of environmental studies. Ekistics (the study of city and area planning) is an outgrowth of environmental concern (Brandwein *et al.*, 1971). There are marked geographical differences in environmental problems which are relevant for biology education; even within a given country such as the United States, the problems may take the form of air pollution in California, water pollution in Wisconsin and land use in Hawaii. National concerns such as public health, agriculture and fisheries find a place in biology curricula. The potentially cancerous growth of human population has given rise to one of the biggest recent efforts in new curriculum developments - the field of population education (Viederman, 1970). Sex education is an important concern in some countries. The chapter on examinations observes that 'group assessment lays emphasis on co-operation rather than competition; this is seen by certain socialist countries as a most important aspect of moral education'.

Social and humanistic concern is one of the roots of some other aims of biological education, such as the aim of developing innovative practices among students, and the aim of developing innovative practices among students, and the aim of cultivating a sense of *internationalism*

in science. The development of innovative practices commonly takes the form of investigational work done by students, resulting in the creation of new knowledge (Thornton, 1972; Tryon *et al.*, 1973). The importance of ecology both at global level (as with such topics as tobacco smoking) and at the local level (as with such topics as forestry in Finland) needs to be stressed.

PURPOSES AND OBJECTIVES ARISING OUT OF THE ETHOS OF THE DISCIPLINE OF BIOLOGICAL SCIENCE

A profession tends to look after its own affairs and perhaps even to extend its influence upon related areas of human activity. The biologists, through their professional associations, were a powerful influence in the great curriculum movement of the 1960's. BSCS arose in this way, and Nuffield Biological Science was fully under professional control. A little later, college biology in the United States came under the influence of the Commission on Undergraduate Education in the Biological Sciences (CUEBS) (Kormondy, 1972).

The aims and objectives for biological education as proposed by professional biologists are likely to be much influenced by the ethos of the discipline of biology. This influence has taken two main directions:

- to make the subject matter of the biology course fairly representative of the field of biology as a whole and of the most important communicable recent advances in biology;
- to make the student work like a professional biologist in solving biological problems.

These two directions have had decisive effects on the general biology courses prepared for children aged around 14 or 15 years; the most outstanding examples of the 1960's were the three versions of the BSCS ('blue', 'green' and 'yellow') and the Nuffield biology texts for 'Ordinary level' in England. Extension of this influence to all school levels is seen in some new programmes such as 'Currently Credible Biology Concepts for K – 12' experts in biology (Thompson, 1970). Professional biologists are invited to prepare course content in various areas of biological science such as conservation (Ronfeldt, 1969; Roth *et al.*, 1970) and marine science (Mangelsdorf, 1966; Driscoll *et al.*, 1972). Space biology is receiving attention (Lee *et al.*, 1969). The same professional desire for representativeness is seen at college level (Lewis, 1973).

Keenness to make a biology course 'modern' can, of course, lead to monstrosities: the chapter on examinations observes that 'there is evidence from essay type answers that the inclusion of complex and difficult material such as metabolic pathways and molecular biology has led to excessive rote learning'. The paper on curriculum evaluation opines that 'it may well be that current popular concentration on molecular biology, quantitative biology, genetic engineering and other similar topics does not contribute to the solution of problems in regions where resource books are badly needed on environmental questions and the systematics of local organisms'.

Apart from updating the content of courses, professional biologists have also interested themselves in a connected aim - that of funnelling the products of current and older research in a country into its school system, e.g. Sri Lanka (Basnayake, 1975).

The second main direction which came from the professional biologists was that of making the biology student into a miniature professional himself. The student must develop the ability to sniff out a biological problem, and to communicate his findings. The emphasis is on biological science as a *process*, a way of solving problems. It is claimed that process is steady while product changes (Connelly, 1972). The inclusion of process became a status symbol in biology curricula (Saunders, 1972). Claims are made that the new curricula are better at teaching the processes of science but some of these claims are disputed (Strauss, 1970). The Nuffield A-level Biology Project included among its objectives that of training the student to 'make

creative contributions to investigatory and problem-solving studies' (Kelly, 1972).

THE INFLUENCE OF GENERALIZATIONS ABOUT LEARNING

Several generalizations which form part of hypotheses of learning have had a powerful influence upon the choice of aims and objectives in education. Examples are given below from the field of biological education.

Generalizations

The generalization that subject matter which is interesting to the learner is learnt better than that which is not

This has led to the excision of 'bad old' objectives such as the learning of taxonomic details in botany and zoology and to the inclusion of objectives such as the learning of human material and fashionable topics of current personal, national and international interest. This is especially marked in the development of materials for slow learners. BSCS has developed such a set of materials called *Me and my environment* and *Me now* for educable though mentally handicapped (EMH) children. BSCS has also developed *Human sciences* for 11 - 13 year old normal children. Students are given a choice of activities within each unit of study.

Conflicts can arise between the desire of the teacher to make things interesting and some of the objectives of biological education such as representative coverage of the discipline of biology or drills in biological skills. The conflict may be resolved by compromise (e.g. by rejecting the notion that everything should be interesting) or by rejecting the original objective (e.g. students may be allowed to select 'concept packs' which interest them in a Principles of Biology course).

Learning theory also suggests that very strong affective involvement can reduce the amount of knowledge which is learnt (see above).

The generalization that items of knowledge must be organized and hung on a meaningful framework

A meaningful framework does not necessarily mean an interesting framework. It denotes a logical cognitive structure arising out of the nature of the subject matter itself. The objective that emerges is that of learning this logical structure. In conservation education in grades K - 16 in the United States professional conservationists have agreed that topic organization is a more useful conceptual structure of the subject matter for learning and teaching than the agrarian-focussed conservation concepts which are common in schools (Roth, 1970). Models for a biology curriculum can be constructed in terms of a psychological learning theory such as Gagne's hierarchical learning theory. Ausubel (1970) considers that there is an overemphasis on process (inquiry, activity) at the expense of the cognitive structure of the subject. He stresses the importance to the learner of using 'organizers' - abstract, general and inclusive statements received by the learner prior to new learning tasks so as to provide anchoring ideas in the learner's cognitive structure (see chapter on 'The understanding of the learning process and the effectiveness of teaching the classroom laboratory and field'). With elementary school biology majors as testees it has been found that the aim of acquiring a body of knowledge and not only that of skill in thinking can arise from learning theory which holds that meaningful verbal learning depends both on the learner's store of knowledge and his analytic skill (Klopfer, 1969).

Learning by doing

This doctrine has been one of the factors that led to the aim of getting biology students to practise biological science like miniature professionals. It may help learning but the laboratory approach is not the only valid road to the learning of biology, any more than it is for nuclear physics, and alternative approaches have been described (e.g. a socio-historical approach to biology) (Boles, 1968).

Transfer of training

The psychology of learning has for decades been sceptical of the assumption which teachers tend to make that the principles which they teach will be applied by the learners to situations outside the classroom. This scepticism concerning the ready transfer of training has led to the inclusion in courses of the objective of training the student to apply his knowledge to new situations, and the objective of learning specific topics in applied biology and not leaving it to chance.

Behavioural objectives

Performance objectives and instructional objectives are those which specify the behaviour to be expected of the learner to show proof that he has learnt. They make it clear to the learner what exactly he is expected to be able to do as a result of who has not been given behavioural objectives, and they make it clear to the teacher and examiner what exactly they are entitled to ask the learner to do to show that he has learnt. An objective such as 'the student should learn the classification of vertebrates' is not a behavioural objective (and may be called a 'pre-objective' if a separate term is necessary (Korgan & Wilson, 1973) while 'the student should be able to state the name of the taxonomic class to which the lizard belongs' is. Behavioural objectives are written with verbs which describe the student's expected performance, e.g. he 'writes down', 'states', 'focuses' (the microscope), 'draws' (a graph), and so on.

The Nuffield A-level Biology Project used the behavioural objectives shown in table 4 for evaluation of the overall achievement of students (Kelly, 1971). They were called 'behaviour systems'.

Table 4. 'Behaviour systems' in the Nuffield A-level Biology Project.

A. Recalling a wide range of biological knowledge involving a choice of alternatives and an understanding of relationships.
B. Writing essay accounts of designs for investigations and explanatory descriptions of biological topics.
C. Solving written problems involving biological data.
D. Acquiring, understanding and utilizing information from reading and relating it to other knowledge.
E. Undertaking practical work and recording and handling the results obtained.
F. Undertaking a project involving the operational divisions:
   - statement and consideration of problems in the area of special interest;
   - selection of a limited topic for practical investigation;
   - investigation of background knowledge;
   - planning the investigation;
   - recording the data;
   - interpretation of the data;
   - relating the interpretation of data to the background knowledge and suggesting further investigations;
   - compiling a bibliography and acknowledgements;

The development of self-instructional devices, in which the student also tests himself to check whether he has learnt, has stimulated the practice of writing behavioural objectives. The tests are constructed to test the behaviours which have been specified. The practice is common in audio-tutorial courses and computer-managed courses.

Behavioural objectives have also gained popularity in situations where a number of schools in a school system use the same curriculum materials and it is desired to have a reasonably common standard of learning throughout the system. They are used, for example, in the 'Comprehensive Monitoring Programme' (CAM) in Sequoia Union High School District, California, and the BSCS *Human sciences* for middle school.

Behavioural objectives have also been written for some introductory biology courses in college (Creager, 1973), and for teacher training.

Lists of behavioural objectives tend to be long and unattractive. They may also tend to deal with the relatively trivial details for which behaviours can be easily specified (e.g. shown a picture of a common vertebrate, the learner should be able to identify it verbally as a fish, amphibian, reptile, bird or mammal) and to ignore behaviours which are more difficult to specify in a manner which will be of real use for practical testing to determine whether the objective has been achieved (e.g. love and respect for living organisms, or the habit of reading biological literature). Frazer (1975) has listed the arguments for and against the practice of writing long lists of objectives. Among the six advantages he lists is the following: 'the teachers and students are in harmony; there is no confusion about what each is trying to achieve; the student is clear when incidental or illustrative material is included in the course'. And among the seven disadvantages which he lists: 'students react unfavourably to the 'spoon-feeding' and 'brain-washing' which are implied in this approach.' There is at present no evidence whereby to decide whether defining objectives helps the learning process (as opposed to the planning of courses and the design of examinations).

Behavioural objectives are tedious to write, just as test items are difficult to prepare. Agencies are likely to arise for trading in the former, as they have arisen (and become big business) for the latter. There is an Instructional Objectives Exchange, Biology 10 - 12, organized by the Centre for the Study of Evaluation, California University, Los Angeles.

An annotated bibliography on behavioural objectives is found in Bingman (1969).

Learning to learn

Learning theory - supported by common experience - suggests that there are some general strategies which apply to the learning of various kinds of material. If the student is given training in these general strategies of learning it can reasonably be presumed that he will more easily become a lifelong learner. This viewpoint has given rise to the objective of 'learning to learn'. It has inspired the production of masses of supplementary curriculum materials, especially booklets on biological topics.

OBJECTIVES ARISING OUT OF A CONCERN FOR THE TEACHER

It may seem curious to speak of objectives primarily in favour of the teacher rather than of the student. But a teacher, after all, must be given time and opportunity to acquire depth of study and experience. One of the objectives of self-instructional programmes is to save the teacher's time. This is often explicitly stated. For example, the course in college-level soil science called the SLATE programme 'saves time' (Foth, 1967). A conference on the teaching of medical laboratory technology advises the use of self-instructional materials 'to save instruction time' (*Manpower for the medical laboratory*, 1968). One of the objectives of getting senior students to teach juniors in college is to enable teachers to find time in which to update their knowledge

(Wise, 1968). This sort of objective applies to teaching methods and materials, while leaving the objectives of the biological education of the learner himself undiminished.

OBJECTIVES WHICH ARISE OUT OF A CONCERN TO PUT AVAILABLE TECHNOLOGY TO USE

We live in a world which is full of technology. Some educators feel that school curricula do not reflect this at all and that the result is technological illiteracy. Computer technology has added new objectives to biology courses, e.g. simulation in ecology at university level. Side by side with this, the old objective of learning to improvise simple apparatus also survives (Lockard, 1972). The working paper on educational technology observes that there have been cases of 'a veritable squandering of funds in the installation of sophisticated and complicated equipment conveying merely trivial messages, or rather, information which less onerous means like a simple blackboard for example could have done as well.'

OBJECTIVES ARISING OUT OF A CONCERN FOR RELIGIOUS BELIEFS AND CULTURAL PRESSURES

Should one objective of biological education be that the student should learn the biological aspects of human reproduction? Cultural pressures make the teacher draw a line somewhere between no teaching at all and practical training in sexual techniques. BSCS felt it was a bold step in the early 1960's to treat all parts of the United States alike in regard to the teaching of human reproduction and of evolution in the BSCS materials (Grobman, A., 1969). If biology curriculum materials were left entirely to the goodwill and sensitivity of the trade, the result would be quite different; the customer comes first in the ethos of the marketplace and his education second.

A striking example of religious pressures is the evolution controversy in California (Wenner, 1973). Should it be an objective of biological education to have the student learn all hypotheses concerning the origin of species, even if some of them are dead hypotheses as far as the biological profession as a whole is concerned?

The work 'anti-intellectualism' is often heard during discussions of cultural pressures. It usually denotes suspicion and distrust of the intellect as the sole or even the chief criterion of value in education and life. It denotes a desire to open the window to other dimensions of experience such as outflows of feeling and inflows of grace. It rejects 'academic rigour' as the highest criterion of respectability in education. Its influence upon objectives of biological education may be seen in connexion with such movements as outdoor education, environmental education and population education. These movements do not reject the intellect; they value it and use it, but they go beyond mere academic rigour into the realms of respecting, appreciating and loving the objects of their study.

THE 60's AND 70's

Trends which were a focus of attention in biological education in the 1960's and which continue to be so in the 70's may be short-listed as follows:

thinking, inquiry, discovery in the learning process;
processes of science;
relevance: local flora and fauna, local data;

meaningful topics;
discipline: representativeness and up-to-dateness;
technology: simple inexpensive equipment.

Trends which are stronger in the 70's than in the 60's.

– Cognitive domain.
  Emphasis upon ecology, population problems, social biology, national needs.
  Greater flexibility in choice of subject matter by students and teachers.
  Encouragement of student research.
  Integration of subject matter.
  Adult self-study.
  Behavioural objectives.
  Sex education.
– Affective domain.
  Greater attention paid by educational scholars to affective areas.
  Greater freedom and responsibility for the student to choose his subject matter and time.
  Greater attention to the student's individuality.
  Greater attention to subject matter's relevance to individual and social interests.

Trends which were a focus of attention in the 60's but are less so in the 70's.
  Training undergraduates to become future professional biologists.
  Use of prestige groups in the profession.

New trends in the 70's
  New technology introduces new objectives.
  Religious differences.

NEGLECTED PURPOSES AND OBJECTIVES

Those who directed the great biology curriculum reform movements in the 1960's were firmly convinced that certain important purposes of education had been neglected by the textbook and science equipment market. These purposes were meaningful knowledge, up-to-dateness of knowledge, the experimental approach, and skill in the processes of science. In achieving these goods, the problem of finding time in the classroom timetable was generally solved by excising much of the traditional content of biology courses, and by sacrificing if necessary the principle of meaningful knowledge.

Such commendable purposes as training the biology student to write reports in the style of the professional biologist, training him to discern gaps in knowledge and the limitations of science, and training him for lifelong learning were recognized and acted upon, but with questionable success. The importance of the affective domain was recognized in passing but when Hulda Grobman (1970) reviewed the work of the 1960's, she wrote: 'Not widely recognized by projects is the fact that achievement of all cognitive objectives requires parallel, concomitant achievement of affective objectives. Regardless of the long-term, primary goals of the curriculum project, perhaps such affective outcomes should be the most important areas for project concern.' Much has been thought and written about the affective domain in biology education but a great deal of the effort seems to have gone into developing feelings for nature and much less into developing knowledge itself (see above). It is sometimes even asked whether any or the proclaimed new purposes of biology curricula have really been achieved (Strauss, 1970).

It may seem futile in this context to ask whether there are still some purposes which even the major reformers neglected. The question must, nevertheless, be asked in the interests of the improvement of education. What about objectives such as training the student to develop his own unique gifts? To develop skill in skimming and extracting the essence from

books?[1] To develop the habit of going straight for the tables and graphs of data in a paper before reading the text? To develop skill in noticing whether an author cites arguments not only for his thesis but also against it, and winkling out the assumptions which the author is making? These objectives are not specific to biological education. The question is whether they are important enough and feasible enough to find a place in biological education. If the answer is yes, there arises the paramount question of how this can be done.

Among other objectives, biological education should not neglect the area of human relationships and family-life education.

ASSUMPTIONS AND PROBLEMS UNDERLYING STATEMENTS OF PURPOSES AND OBJECTIVES

Assumptions

A neat and simple flow chart could depict the orderly process leading from aims to content, to methods, to learning. Now consider the many assumptions which underlie it. First, it may suggest that aims and objectives need to be stated more or less precisely in words and not merely vaguely. If so, there is the further assumption that aims can be put into words. Words are not the same as things. Is it at all true that a major aim of 'education' is to keep children out of mischief[2] and to attach some kind of label to them for future reference? If so, is it ever put into words in a statement of aims? If not, why? There may be reluctance to verbalize some of our strongest convictions.

If the statement of aims is for use not only by oneself but also by others, we must assume that the words mean the same to everybody. It is also usually assumed that the curriculum-maker (and not the funding body or the students or the market agent) is the best person to state the aims. It is further assumed that the statement of aims does determine or at least seriously influence the preparation and use[3] of curriculum materials and the evaluation of the curriculum and of the student's learning. A good example of the evaluation of a curriculum, and indeed of the evaluation of the aims themselves, is found in the Nuffield Advanced Biology Project (Kelly, 1971)[4]. There is likewise a tendency to assume, that the short-term aims (if these are distinguished at all), such as might be tested in a school examination paper, do really support the long-term aims (such as those for adult life). Assumptions of this sort are naturally difficult to test. One example was the discovery that a community which had had conservation lessons in school showed better knowledge of, and attitudes towards, conservation than did a community which had had none (Solid, 1971).

Emergent objectives

Instead of writing out the objectives before working on the content and method of the course it is possible to write them while the course materials are being prepared. In the former case

1. Shepherd (1960) wrote a book on effective reading in science. There are chapters on reading in science (values, reading abilities needed, basic steps needed in teaching reading skills), diagnosis in the reading of science, skill in varying the rate of reading according to aim of reader and nature of materials, skill in using parts of a book, skill in locating and using sources of information, ability to use correctly the vocabulary of science.
2. 'Let's be honest; if you want to send the children out for babysitting, send them out babysitting. Send them out for social experience, to learn to lead parades, or whatever you want them to do, but don't let's confuse our objectives.' (Fuller, 1969).
3. The directors of curriculum projects are frequently surprized when they ask whether the teachers who reach the curriculum materials are really clear as to the aims of the curriculum (see e.g. Kelly, 1972a).
4. 'The objectives of the trial course were conceived more as hypotheses than as absolutes, bearing a similar relation to the trials as a hypothesis to an experiment and capable of being proven, disproven or modified. Indeed some objectives were abandoned after the trials and some unforeseen outcomes of the trials resulted in new or modified objectives being introduced for the revised scheme.'

the objectives are pre-set, in the latter they emerge out of the course. Emergent objectives have the disadvantage that they do not guide the preparation of the course but the advantage of possibly being a truer reflection of the purposes of the course.

A type of evaluation which may be allied to the philosophy of emergent objectives is described in the chapter on curriculum evaluation as 'responsive evaluation', the proponents of which 'differentiate their views by treating objectives, hypotheses, test batteries, teaching syllabi, etc., not as the basis for evaluation but as components to be evaluated themselves... Responsive evaluation has the built-in flaw of excess subjectivity and serves a more casual, less scientific way of reporting.'

When the Nuffield A-level biology curriculum was being evaluated after school trials, new objectives emerged: 'some of the successes of the project were not anticipated, e.g. studies using simulated habitats, those concerned with the relation between mathematics and biology, and aspects of project work. Should these unforeseen, beneficial outcomes become objectives of future evaluation?' (Kelly, 1972).

Revision of objectives

Scant attention has been paid to the problem of revising a list of objectives as the curriculum is put into practice. Clues for revision can come from the growing insights of course-makers and teachers, and from feedback from the classroom. There should therefore be a continuous re-appraisal of the objectives of biological education.

Consistency between objectives

There may be open or hidden conflicts between objectives. Thus the objective of learning a body of established knowledge (in a limited time) may conflict with the objective of learning to ask for evidence all the time. This situation can be met by changing the latter objective into 'learning to handle evidence' or (less easily) by reducing the former objective so that the body of knowledge to be learnt is conveniently small.

Desiderata

Full-length studies of problems relating to purposes and objectives would not only help persons who are about to prepare a list of objectives but also help give direction to the purposes of education in the future. The chief problems that await solution in the field of biological education include the following:

1. To what extent do lists of pre-set objectives influence the preparation of curriculum materials and their evaluation?
2. Are emergent objectives more realistic than pre-set objectives?
3. How many major aims can a teacher effectively keep in mind in classroom practice?
4. How are hidden conflicts between objectives resolved in practice?
5. What are the mechanics of revising lists of objectives?

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Trends in the biological component of education at the primary and junior secondary levels

INTRODUCTION

It is difficult to speak of biology teaching outside the global educational context and without reference to the social and economic factors which govern it. These elements vary greatly from one country to another and consequently it is not possible to suggest a single teaching (didactic) model. The comparative study of the different curricula enables us to pick out certain trends, facilitates the analysis of data, and decision-taking at the specific level of each country.

Not all the projects relating to the subject could be consulted because of considerable documentary problems. The projects cited are only examples aimed at making the analysis more concrete; they show the importance of international exchanges which the Uppsala Congress was meant to develop.

This chapter is limited to the teaching of biology during the first nine years of schooling. It is centred around the problems characteristic of this age group. During this period, biology

teaching does not aim at training specialists but at contributing to the general development of the child so as to make his or her social integration easier. It involves mass teaching even when the course of study is not compulsory. At least during the first years of this period, curricula are the same, whatever the capacities of the children may be.

FACTORS EXPLAINING THE EVOLUTION OF BIOLOGY TEACHING AT THE PRIMARY AND JUNIOR SECONDARY LEVELS

Various factors have had an impact on the evolution of the discipline and have brought about a profound change in teaching methods since the second world war. Some of these factors apply specifically to the teaching of biology at the elementary level.

Development of ideas on the subject matter of science in general and of biology in particular

The rapid development of the sciences has drawn attention to the part played by the human mind in the construction of science, and has contributed to the dissemination among pedagogues of an image of science closer to that held by the scholars and the historians of the sciences. The systematic participation of scientists known for their research has contributed towards disseminating such a concept more rapidly. The scientists' analysis emphasizes the following points:

Science cannot be defined as a collection of facts grouped to satisfy theories. It cannot be defined as a body of facts which grow quantitatively: scientific knowledge is built up by an active effort of the human mind which questions anthropomorphic and naive interpretations. A scientific definition such as that of the species, the enunciation of a law such as the influence of light on the behaviour of the earthworm, requires some elaboration of data by logical processes after the observations are made. Such conclusions lead to the rejection of three ways in which young pupils are often introduced to science:

- an introduction to science cannot consist simply of a use of the senses (the so-called lesson in observation; this is a scientific exercise only if the effort of perception is orientated by questions which lead to the establishment of relationships, the separation of variables or the elaboration of a plan of organization;
- an introduction to science cannot be a single learning of techniques (how to rear a hamster, for example); it begins only when an effort is made to analyse practices in order to derive principles which can be transferred to vary different situations;
- science cannot be transmitted by a simple statement which is then memorized by the children. It is only the knowledge built up after an active approach which can be incorporated into daily life.

Science education must not stifle creativity, curiosity and a critical attitude toward one's own opinions and those of others. By definition, scientific thought is expected to re-organize itself in the light of experience. It is only present among those who know how to identify a precise problem in complex situations where all the factors are mixed. On the other hand, scientific activity is a social activity which is based on oral or written discussion. A false image of science is given by exclusive reliance on textbooks.

At all levels of learning, methods are inseparable from concepts even if the study plan only mentions one or other group of objectives. Scientific method must not be regarded as a unique and infallible recipe, but rather as the set of procedures which allow one to find out a solution to a problem. The correct application of (scientific) method leads to valid knowledge, even for the young child. Attempts are often made to impose explanation levels which are thought rigorous i.e. as close as possible to university knowledge, whereas it is more important to propose

statements which could explain the facts noticed at the level of a child's logic, and to look for a new formulation when a new fact contradicts the previous statements.

In a parallel way, ideas on the content and methods of biology have greatly evolved in pedagogical circles.

In the majority of study plans of the 1950's biology was still considered as a science of factual observations by contrast with physics which was claimed as an experimental discipline with a strong mathematical bias. As observation was habitually considered the only scientific operation available to the young child, biology was often the first scientific discipline taught. Teachers trained during this period were often lovers of nature, but their detailed analyses often lacked direction. Above all, classroom work predominated; science lecture rooms were often veritible museums overcrowded with collections of animals and plants and osteological specimens. Morphological, anatomical and systematic studies were therefore emphasized and led to the memorization of an important vocabulary. Practical work was introduced in a fairly general manner but with closely defined programmes of work and as applications of the course. They accorded an important place to observational drawings.

Since 1950, pedagogy has taken account of the slow evolution of biology at the research level. Owing to the development of physiology, of general biology and biochemistry, attention has focussed on the study of manifestations of life and its functions, on the action of environmental factors. This evolution has lead to a closer link with the physical sciences for two reasons: it has been necessary to rely on the concepts of physics to give a sufficiently precise or even general definition of functions such as respiration or nutrition in plants; biology so conceived, relies of necessity on experimentation and measurements; it appears as an experimental science for the same reasons as physics. This marks a positive and probably irreversible change despite certain distortions at the level of the age category under consideration.

On the one hand, the study of functions was made from a purely analytical and rather fastidious viewpoint. Students were not always prepared to ask the relationship between functions, the regulatory mechanisms, the unity of the organism. The precise study of the relationship of a species with its environment was often neglected.

On the other hand, because of the predominance of biochemistry and molecular biology in university training, teachers were not always prepared to define the physiological functions (respiration, reproduction, etc.) in a concrete way, intelligible to young children, they imposed a physico-chemical interpretation, poorly understood, without overcoming the obstacles that the situations under study present to the interpretations of general biology; e.g. respiration was presented as the balance sheet of gas exchanges to children who were ignorant of oxygen and CO_2.

These two difficulties can be solved provided that the notions taught at this level are not considered as a simple summary of what the teachers have learnt at a higher level.

More recently the development of ecology and technology have revalued the field disciplines without thereby eliminating the necessity for laboratory experiment. Several reasons account for the shortening of the usually considerable period of time which separates the re-organization of university studies from their effect in primary school classes: the cinema and television have stimulated interest in the study of animals in their natural habitat; the environmental crisis has drawn attention to the balance of nature; young children often ask questions about these problems.

A renewed interest in the study of man, frequently neglected in the projects of the 1960's, may also be noted. It is no longer a matter of physiological study allowing a comprehension of the rules of hygiene but of a global approach seeking out the interference of biological and social factors in human problems.

At the same time, the ecological vogue has also brought with it a few pedagogical illusions; schools have sometimes been submerged beneath a welter of documents of mediocre quality which have masked the fact that ecology, a discipline of synthesis, could not do without

precise analytical studies having a bearing on functions and behaviour.

Evolution of the concept of relationships between science and society

During the years following the second world war, there was a considerable gap between the evolution of industrial society and the content of scientific programmes: scientific research had become the essential driving force of development and an instrument of power at the service of States, while secondary scientific education took on an academic and uninteresting image, the study of applied knowledge had little place in teaching, and the preparation for 'decision making' was through a literary, juridical and eventually mathematical training.

By contrast the teaching of the sciences seemed to play a greater part in primary education; but it was mostly a kind of pseudo-scientific process aimed at conveying practical rules in hygiene, in agriculture and in domestic economy. The sterility of an education based on recipes which rapidly became out of date together with the development of secondary education have brought about a recession in this teaching of applied sciences in all countries where the duration of compulsory schooling has been lengthened.

Finally, a scientific programme sometimes served as an ideological support to political training; but the consolidation of power has made this instruction superfluous.

During the period from roughly 1950 to 1960, the majority of young people emerging from compulsory schooling were incapable of understanding the technological society in which they lived, nor were they able to adapt to important changes in their way of life or to participate effectively in decisions about public life.

About 1960, a series of events suddenly made public opinion sensitive to the role of science in development. The emotion aroused by the launching of Sputnik (1957) enabled considerable funds to be got together for the improvement of scientific education in the United States; in several industrial countries the research into the teaching (didactics) of sciences has received important subsidies from the space, automobile or chemical industries; biology has therefore sometimes been neglected at the expense of physics. Over the same period, developing countries, in pursuit of a pedagogy adapted to their needs, have sought to renew their scientific instruction.

The new needs have revealed the ineffectiveness of the premature teaching of factual knowledge and of technical recipes which give rise to mental rigidity at a time when the need was for adaptable minds, capable of analysing a situation in order to solve a problem or participate in decisions. In a decade, a new image of science - science as it appears to the researchers - was popularized: it lays stress on the scientific attitude of mind, the importance of creativity and the necessity for communication in scientific approach. It gives value to the experimental method which allows one to reason on the basis of what is possible, and solve a problem without applying non-transferable recipes; it reveals the acquisition of knowledge as a spin-off from the well conducted approach and places the accent on the learning of basic concepts. The new curricula and the numerous projects for research in this period show several characteristics in common.

– The almost universal adaption of the method of discovery whereby the activity is centred on the solving of a problem raised if possible by the children themselves. After more than a century of cautious routine, this method has perhaps too rapidly received official approval.
– The development of integrated science teaching at this school level which brings together biology and the physical sciences. This integration facilitates the formulation of problems stemming from the environment in which the physical and biological factors closely overlap. It also makes apparent the unity of the scientific approach.
– Early scientific instruction has been introduced, if possible from the start of primary school when the mastery of language allows. According to numerous authors of projects it is only on this condition that the scientific attitude develops fully and leads to the systematic

organization of data from experiments instead of being limited to the training of specialists. Nevertheless, certain Eastern European countries give priority to the learning and mastering of the written language and of mathematics in order to avoid the accumulation of factual non-integrated knowledge.

The liaison between the development of the sciences, economic progress and human happiness, was generally admitted about 1960; but in the course of the last decade this liaison has been more or less questioned for different reasons depending on the countries concerned: the relationships between sciences and society are indeed more complex.

In developing countries, the conflict between scientific thought and traditional culture has been closely analysed. It is not a question of denying the need for scientific training which conveys a system of notions fundamental for development - the idea of an order in nature accessible to knowledge, and that of the power of man to transform it to his own advantage. Scientific training also helps in the mastery of the experimental method which alone provides the tools for prediction applicable to a new situation in continuous change, while empirical experience, set rigidly by tradition, is based upon the observation of a static situation. But traditional culture, under the guise of ritual practices, has achieved the intuitive synthesis of a great number of data which has allowed the group to survive. Not only must the scientist be able to recognize the positive aspects of this experience in order to be capable of conducting a dialogue and assuming rural animation, he must also have the humility to recognize that his knowledge, built on limited experience relative to other situations, has gaps and that there is always something to learn from his environment. In more general terms, the school is not called upon to set up an enclosed milieu, resistant to all the contributions of traditional education, but a meeting place between generations and ways of thought.

This preoccupation has led numerous countries (French-speaking western Africa, New Guinea) to integrate biology training in a global approach to the environment which binds closely together natural science, social science and civic education. This is usually achieved by excursions and enquiries, but in an increasing number of countries the tendency is growing to make the children take part in work that is productive (Tunisia, Cuba), such work being considered as an assumption of responsibility and a source of experience (a point of view, moreover, shared by such industrialized nations as the German Democratic Republic).

In the developed countries, the crisis of industrial society has presented the aims of scientific training in a different manner, and sometimes even the objectivity of the sciences has been disputed. Two new questions arise in connexion with recent projects from the elementary school onwards:

- How should the child be trained to grasp the immediate and more remote repercussions of individual or collective activity designed to maintain biological equilibrium, to manipulate the environment in a harmonious manner and to manage rationally the natural resources at global level?
- How does one succeed in knowing man better in order to assure his survival and his well-being? In the present day he is threatened in developed countries more by the change in his way of life than by microbes. The crisis of values has led to the analysis of interference between biological and social factors in human behaviour (sexuality, place of the human species in the living world, origins of aggression, unity of the human species confronted with racial and cultural differences). The sciences are not asked to found a morality but to help with the object study of personal values and the understanding of different patterns of behaviour.

As in the course of the preceding period, biology training is centred on the capacity to analyse the problems posed by the environment, but attention is now focussed more on the responsibility of man, and the necessity, as well as the difficulty, of decision-making; there is not necessarily a single simple solution to all the problems (National Pedagogical Institute of Kiel, BSCS).

On the other hand, the concern to integrate disciplines, if still as marked, tends to take on a less uniform shape than in the course of the preceding period: biology no longer appears as a simple component of the natural sciences but as the bridge providing a link between the physical sciences and human sciences.

Evolution of ideas concerning the role of the school in the development of the child

In the course of the last few decades, the idea that the school must be at the service of the child's development has ceased to be a wish expressed by those promoting the new education and now appear as a social necessity, as the very condition of the effectiveness of social necessity, as the very condition of the effectiveness of school learning processes. The lengthening of compulsory schooling in the majority of countries has enabled the obsession with fundamental skills (reading, writing, arithmetic) to be overcome and to give way to a search for conditions of training more in accordance with psychological findings. In a rapidly evolving society, the development of creativity, of initiative, of the capacity for thought and self-teaching are much more important than rigid skills. Education can no longer merely reproduce the society of grown-ups. Zamkov's formula 'we wish to train creators, not executants' is implicit in most curricula.

Psychology has clearly demonstrated that the effectiveness of fundamental skills, the ability to use them in a useful fashion, and the reduction of scholastic wastage, were largely conditioned by a pedagogy of awareness. The child builds his knowledge from personal effort; the role of the teacher is to motivate, to supply him with suitable starting points and to help him to overcome obstacles, but not to impose upon him a ready-made knowledge.

Child psychology has made it possible to define precisely the conditions and functions of early instruction in biology. Its role is not to control the content or impose methods, but to help adapt to a specific age contents and methods recognized as valid by biologists and which also perform a true educational function in the eyes of society.

During the age period concerned, the child gradually develops causal thinking. In biology more than in physics, he tends to explain phenomena and structures as the will of the organism. He sees the organism as a collection of functions, without trying to explain these functions through the organization of the whole organism, without objectively linking these functions within a functional unit. It is only when he is faced with a concrete problem (for example, the survival of animals collected in a pond) that he will try to discover a causal relationship which will allow him to fulfil his objective. He will therefore build up an increasing number of 'islets'. which are relevant to scientific thought, and not to animism or anthropomorphism. On the other hand, the child does not understand the experimental approach. He has difficulty in methodically separating the variables; in conceiving the role of the hypothesis as something which will confirmed or invalidated by experiment. He does not regard models as the basis of deductive thought, but as a photograph of reality. All these aspects refer to the formal thought (Piaget) which is achieved by most children between 12 and 14 years of age. It is not effective to increase the number of experiments: the child considers them as school rituals which serve a dogmatic statement. On the contrary, even young children can find a solution when they have been able to pose the problems themselves, starting from a concrete situation, and when they can organize a free discussion in the classroom. When the empirical approach is built up afterwards, the logic of the experimental approach is discovered.

The difficulties previously mentioned have led to the rejection, as far as young children are concerned, of a biological education centred on the accumulation of a factual knowledge, and the learning of incomprehensible practical rules, such an education is not neutral, it delays intellectual growth. Two different solutions have been sought. Some Eastern European countries (USSR, DDR) have preferred to reduce the importance of scientific education, including biology,

during the first few years of scholarship, in order to develop the mastering of language and logical thought through mathematics. An informal biological initiation can however take place through gardening and undertaking rearing activities. In other regions, the introduction of biology is advocated, not only to ensure the affective equilibrium of children in an urban environment, and to enable them to understand the practical measures for hygiene taught in school, but also to effectively integrate scientific activities into their general development. Such an approach prevents failure due to verbal teaching far removed from the interests and experience of the children. Projects of this kind have the following characteristics: the development of the scientific attitude (curiosity, inquiry, creativity, self-confidence, etc.) is stressed and it is at this level that the child's scientific thought is near to that of the researcher; the encouragement of an active build-up of knowledge, the child being allowed to express his own spontaneous conceptions, which he can check through independent investigations, and discussion with other children.

The preceding remarks show that the aims in biology teaching have considerably changed since 1950. It has ceased to be a second-rate discipline, a pleasant pastime of a jumble of knowledge with scant scope for reasoning. It has become a mature discipline, dealing with the most recent acquisitions of human thought, the mastery of the experimental method. It plays a major role in the development of the understanding of man, his physical and biological environment, his system of interpersonal relationships (Australian Science Education Project). But this change of aims implies a change in methods: science and psychology agree in rejecting a dogmatic teaching of knowledge, in favour of an approach where the pupils have effective autonomy, and actively participate in the build-up of their knowledge.

THE PRESENT-DAY TEACHING OF BIOLOGY: PROBLEMS COMMON TO THE WHOLE RANGE OF LEVELS IN THIS STUDY

Problems concerning the formulation and evolution of objectives

Recent study plans are defined in general by tables of objectives, not by linear and mandatory programmes. This change has permitted flexibility in the curricula. It gives teachers an opportunity to choose the subjects of study linked to the environment and the interests of the pupils, and it allows for the competence of teachers and the resources of the school, at the same time fulfilling the table of objectives (methods, techniques, basic concepts) common to the schools of the region. Moreover, while showing the complex network of relationships linking the objectives, the table helps in their formulation and progressive organization, while the linear and closed curricula look like an unstructured body of knowledge without structure.

The tables of objectives are very useful for teachers in classes where the children's activity is focussed on the solution of a problem. If the teacher wants to ensure that the pupils who are investigating in an autonomous way do not waste their time, he should know when and how to interfere with questions, suggestions, provision of material, etc. His decisions are influenced by implicit and explicit objectives. The choice of the teacher is easier if the feasible objectives of a given project (a sample of germinating seeds, for example) are clearly presented to him. Some projects give very detailed lists (Sciences 5/13, Scientific awareness activity in France) not to serve as imposed learning programmes, but as suggestions and possibilities for exploitation in an actual classroom situation.

The tables of objectives have helped define some important aims for the young pupil, such as the development of scientific attitudes, and have made it possible to take these into account in the evaluation process. This has encouraged the development of methods of objective observation of the children. With the aid of tables of criteria, teachers can follow the progress made by the children in acquiring the scientific attitude and methods. It is not enough to establish a table of so-called rigorous objectives, i.e. in agreement with the data of sciences

and psychology, such tables should be manageable by the teachers and should be explained to the children in order to allow them to take charge of their own training. They should be understood by parents so that the school is not cut off from the cultural environment of the grown-ups. For all these reasons, teachers should be closely associated with the choice, establishment and evaluation of objectives.

In many projects, non-cognitive objectives have been considered important: affective objectives, attitude objectives, general education objectives (APSP, different Nuffield projects, projects of integrated science in Scotland, IPN Kiel, awakening activities in France). It is a matter *either* of specific objectives in biology, for example the concern for an affective or aesthetic encounter with living material before passing on to scientific work; the concern to avoid useless destruction and to ensure the well-being of the animals collected; and the concern to avoid environmental pollution; *or* of objectives relating to the scientific attitude in general: curiosity, creativity, critical thinking, finding out the answer to a question through personal investigation; *or* of general education objectives achieved via the scientific approach, e.g. active co-operation, respect for the opinions of others and for the rules of communication, etc. These objectives are sometimes implied (Nuffield Junior Science and Combined Sciences, ESS) by the approach suggested to the teachers, or translated into indicators of behaviour forming a basis for evaluation.

As regards cognitive objectives, the projects place emphasis either on methods (ASS, ESS, Nuffield Junior Science 5/13) or on concepts (SCIS, COPES, Kiel) or on both spheres. In principle, this choice has no importance for the age category concerned. Every well-conducted scientific approach leads to acquisition of knowledge, or conversely the basic concepts in sciences cannot be understood without the method which makes them meaningful and effective. But on the level of concrete pedagogical practice, polarization on to a single family of objectives may mask certain pedagogical errors from the teacher. Imposed concepts instead of being built-up are not understood; method learning through scientific recipes are ineffective. It would be des- irable at the level of teacher training to show the link between the two families of objectives and to make progress along several directions too often neglected.

It is not enough to acquire knowledge. When the child is overwhelmed by television, news- papers and advertisements, the only valuable knowledge is that which allows a critical analysis and an organization of the non-coherent flow of information. It is necessary to rely on exper- imentation to build up basic concepts.

It is necessary to grade the conceptual and methodological objectives according to the dev- elopment of the child. In numerous projects, there is an unwillingness to define the knowledge programmes for each class in respect of children between 6 and 12, as the level of the different pupils is too heterogeneous, but the teachers need to know the different levels of possible form- ulation for the same basic concept in order to be able to individualize their teaching.

For the age category concerned, biology is rarely assessed, and therefore many projects do not mention a table of knowledge, this being reserved to the end of compulsory schooling (e.g. Nuffield Combined Science). Other projects give tables of basic concepts at the end of a cycle or indicate tables of knowledge which are useful for the intelligent learning of practical objectives.

The technical or practical objectives are formulated differently according to the projects:

- The objectives concerning use of instruments and laboratory techniques (techniques of observation, analysis, measurement, recording of data) play an increasing role at the end of the age category studied. Their formulation does not show enough of their general function to the teachers. They introduce progressively a technology different from that of the trad- ition where the instruments are an extension of the hand, while the scientific techniques impose on the user the logic of the instrument and the mastering of the scientific prin- ciples. The evaluation of instrumental learning is often neglected.
- The practical objectives concerning health education and agricultural development remain important in most of the projects of developing countries, but they are better linked to

cognitive objectives instead of being defined by training which resembles a form of conditioning.

Too often practical knowledge is only controlled by theoretical trials and not on the occasion of activities practised in an appropriately responsible fashion in a concrete situation requiring reflection and decision.

Problems concerning methods

Biological initiation involves not only lectures with demonstrations by the teacher, but also practical work, field work and documentary research.

Co-ordination of field studies, laboratory work and documentary research in scientific training

Most study plans recommend excursions, studies on the spot, enquiries among agriculturalists, forest managers, health services, visits to museums and zoological parks; sometimes the children devote themselves to some productive work, as has already been indicated. Field studies seek to react against the verbal and artificial nature of the school situation. They create for the class as a whole a common experience which facilitates the active participation of all the children. Placed at the beginning of a theme-study it is possible thereby to pass progressively to the formulation of one or more problems starting from enquiries provoked by the contact with a situation which is real, complex and already grasped globally (cf. Symposium of Dakar, 1975). The return of the environment at the end of a theme enables children to grasp the role of learnt material in the taking of decisions, and the interference of such material with other factors, economic and social. The child understands that knowledge is not to be recited, but used to transform the environment.

Field studies in general do not suffice to define a scientific approach. The simple editing of replies to an enquiry questionnaire constitutes a fruitful activity for training in the written language but not a scientific exercise. If the child remains on a descriptive level without separating the variables and establishing genuine casual relationships by comparative observations and experimentation, he simply accumulates technical recipes but does not achieve a structured scientific thought.

Field excursions are more difficult in urban environments, in particular for administrative or financial reasons. Certain projects do not mention them. But is it advisable always to work on simplified situations where the interference of biological and human factors cannot be directly grasped? More recently, nature and marine classes have been particularly developed for children in an urban environment. They can be very fruitful, for the reference to two environments which are totally different hastens the awareness of problems. Yet there exist few documents relative to their exploitation throughout the school year suitable for the scientific training of children.

Laboratory work is recommended by all study plans. Despite the efforts made in connexion with apparatus and training, this type of work cannot always take place in certain schools. Would not the desirability of providing laboratory work for all the children of secondary schools constitute an objective requiring top priority? It is necessary to state that practical exercises are not defined by the equipment available in a given place or the complexity of this equipment, but by the effective possibility of observing and manipulating individually or in small groups. In this area the school garden can extend the classroom as a place for experiment.

The form of practical work has considerably evolved since 1950. It was formerly considered as an application of the lesson and devoted largely to technical learning skills and to observational drawings; very precise written directions narrowly limited the pupil's initiative. In certain countries, practical work continues to be considered as an application of the lesson taught, but it requires from the pupils an effort in analysis and logical reasoning in order to apply learnt skills to new situations. However, the generalization of the method of discovery

has led to the practical work being placed at the start of the exercise, after the problem has been formulated. Real autonomy is given to the children, even when they work on batches of material specially designed to achieve a predetermined objective. In other cases, they complete their project by using material freely available to them. The work sheets serve above all in the learning of techniques, while providing suggestions when a group is stuck in its investigation.

The documentary and audio-visual studies make it possible to limit the importance of the teacher's lectures. Provision of information is necessary at the moment of synthesis: observation and experiment lead only to pinpointed results; recourse to documents - different ones if possible - is indispensable in order to control, generalize and assign a place to this knowledge.

Work in small groups centred on the realization of a project - which constitutes a rather large part of the biology curriculum in numerous study plans - assumes a close contact between experimental and documentary activity. Nevertheless, documentary studies must not take the place of laboratory work, but rather complement it. The danger of substitution exists especially when independent work takes place in a documentary centre some distance away from the laboratory.

Method of grouping pupils

The teaching of biology almost always takes place in establishments where the class, groups of pupils of the same age or at the same level, constitutes a stable unit. But within the class, a great part of the timetable is often devoted to work in small groups. This type of work was first advocated to allow pupils to manipulate effectively or exploit documentation. Today it also reflects the desire to give effective autonomy to the pupils and to change the teacher-pupil relationship. The teacher can observe the children and intervene individually with questions and suggestions, he can differentiate his interventions for the benefit of the most disadvantaged pupils. Group work presents a number of problems:

- How many pupils can work together effectively in an experimental discipline? Must one favour the grouping of pupils at the same level or on the contrary group pupils of differing ability.
- How many groups can be managed effectively by the teacher? The number of pupils in classes of practical work varies from 16 to 50 according to the country. The problem arises particularly when the groups work in an autonomous situation at different tasks and the instruction sheets prepared in advance do not give sufficient support.
- Are there sequences in the activities (observation, for example) which are best conducted in groups? Conversely, are there activities which are performed as well or better by the class working as one group.

The teaching of biology in pilot schools has sometimes been more flexible. Pupils have been variously grouped according to the disciplines, and large groups have been taught by teachers working as a term. The following conclusions seem to emerge:

- It is not advisable to group by level of achievement in biology. This discipline appeals to very different abilities (conceptual intelligence, imagination, practical intelligence) so that very different kinds of pupils can collaborate effectively in hetergenous classes.
- The taking over of a large group by a team of teachers is fruitful in as far as it allows greater individualization in teaching and a better utilization of the teachers' skills, but it supposes an adequate infrastructure and an important harmonization in the framework of a pedagogy performed according to objectives.

The discovery method, difficulties, ambiguities and means

The majority of study plans agree in advocating an approach centred on the solution of a problem and achieved by the children in an autonomous situation. This approach does not appear as a luxury reserved for developed countries but is advocated very firmly in the projects of developing countries (APSP, Korea, Philippines, Lome symposium). It is advocated for children

between 6 and 12 years by most teachers except Ausubel. who considers that this approach wastes too much time, a conclusion which seems to be shared by certain East European educators. The arguments for and against the method of discovery cannot be presented here, but it is useful to make some practical remarks:

- There is a close relationship between the hierarchy of proposed objectives and the choice of the educational method. If priority is given to the acquisition of a scientific attitude, to the mastering of the experimental method, to the development of self-learning capacity, it is necessary to allow the child himself to formulate the problems starting from real situations and to allow him effectively to investigate. On the other hand, if priority is given to avoid random search by the child and to provide him with suitable material conceived for the acquisition of a particular concept. Then one deals with the transfer of acquired knowledge to complex situations. But whatever the priorities, it is impossible, for this age category, to avoid need for a period of autonomy when the teacher listens to the child and helps him express himself, nor the necessity for a period devoted to the organization of the knowledge acquired, even when there is no programme of imposed knowledge.
- There is often a substantial gap between pedagogy as described in the projects and as actually applied in the classrooms. Most teachers need work tools: guides, suggestions for research, design and use of equipment. Without adequate training and self-confidence, many teachers abandon a flexible approach which takes into account the questions and the real thoughts of the children. They stick to the questions asked by the book, and only take notice of the answers made by the pupils when they are foreseen by the guides. They finally resort to dogmatic teaching, wrongly called active discovery - centred teaching.
- The revision of biology teaching is linked less to the intrinsic quality of the projects than to the effort of educational activity and of the training of teachers which goes along with the establishment of a new project. Through team work, teachers can help one another and also be external observers in the classroom of a colleague, using, if possible, recording techniques (tape recorder or magnetoscope) and grids allowing an objective analysis of classroom situations. On the other hand, the extension of a project needs the continued instruction of the teachers. Some project authors do not disseminate work sheets and equipment to those teachers who are not integrated into a training network.

The training of teachers

This crucial problem will be only briefly dealt with here, as it is examined in detail in the chapter on *'Developments in the training and retraining of school biology teachers'.*

Training of teachers and educational research

In spite of considerable expenditure during the last ten years, only 30 per cent of primary school teachers have adopted the new science curricula in the United States. A considerable amount of time can be saved by securing the effective participation of teachers. Not only is rejection avoided (as the causes for resistance to innovation are discovered during the research process), but benefit is derived from the creativity of the teachers which has been often underestimated. Teacher training centres tend to become active centres of pedagogical research.

Initial training of teachers

Stress is often laid on the fact that the level of scientific training is low amongst students entering the teacher training centres. To improve this situation, it is not necessary to increase the number of biology courses, but rather to react against the dogmatic nature of the training and the lack of initiative required in the course of study. With such an approach, future teachers become accustomed to solving problems through personal research, team work and the acceptance of full responsibility, all of which develop self-confidence and scientific attitudes. It is

desirable to link more closely scientific, psychological and pedogical studies. The study of concrete cases shows how each of these disciplines can contribute to the solution of a pedagogical problem. One can also help by reducing the importance of theoretical courses which the student cannot use in daily practice.

The re-training of teachers

The continuous training or re-training of teachers has been underlined because of the rapid evolution of biology and the needs of society. Two aspects have been generally stressed: the necessity for active participation by teachers (in workshops, as in the ESS project) and the importance of an effective follow-up system after the training period. In Ghana, the training period is followed by three visits of senior advisers or teachers to the trainee's classroom. In other cases, the members of the same pedagogical team are brought together.

The facilities required

Classroom and scientific equipment

See the chapter on *'The impact of new instructional equipment and educational technology in the process of teaching biology'*. Two problems arise in this connexion:

- Does the change in teaching methods require a change in the architectural design and the furnishing of the laboratories?
- How can one achieve a minimum quantity of apparatus with restricted resources?

The traditional approach makes a distinction between lecture theatres and practical-work rooms. The rooms were specialized according to their functions and their organization was very rigid. The new trends imply the building of rooms suited to integrated teaching and capable of achieving multiple functions with different groupings of pupils: courses with demonstrations by the teacher, work in small groups, a nature corner with cultivation and rearing facilities, access to printed and audio-visual documentation, and free access to all material. It would be useful to encourage exchanges of views relating to the solutions found in different countries and their respective costs.

The new-style rooms can be created very economically. The essential is to have available flat mobile surfaces for working, and storage units. It is also necessary to occupy the existing areas to the fullest extent (in Senegal, scientific blocks are built so as to serve several secondary schools in common).

Expenditure on equipment can be reduced. Part of the material can be gathered on the spot or set up by teachers with help from the children (the Unesco manual has numerous suggestions, African and Asian projects often put forward original ideas for the making of equipment). This work also helps to increase the technological experience of the teachers and pupils. It is nevertheless important, especially at secondary school level, to have available a minimum of precision equipment (microscopes, measuring instruments) and of glassware, in order to demonstrate the role of instruments in science, and to develop the skills these require. Numerous countries have set up national equipment centres which buy, distribute, and sometimes make the equipment kits.

Documentation

Documentation for the teachers

Books available to teachers constitute the main publication effort in most of the recent projects. They contain scientific information, pedagogical suggestions and technical help relative

to the material. The newly appointed biologist, however, also needs information on the local environment and relevant documents, of limited circulation, are much more difficult to obtain, even though indispensable. It is necessary to provide information on practical experiments (guides to pedagogical resources produced by teams of teachers, centralization of information in documentary centres to which teachers have access, etc.).

Documentation for pupils

The textbook, even when wisely used, is inadequate for the specific needs of the new pedagogy in biology. It is often replaced in new projects by an exercise booklet; different textbooks are therefore at the disposal of pupils in the class library.

Group work presupposes the production of specific documentation (technical or documentary sheets, taxonomic booklets) which are not always available commercially. On the other hand, nature books and encyclopaedia often enable information to be found for answering questions when the results of observation or experiment call for complementary information. Some projects put self-evaluation files at the disposal of pupils (France: pilot junior secondary schools).

Audio-visual aids

The role of these audio-visual aids is diverse: to increase awareness, simulation of an experimental situation with a view to analysis, complementary information, evaluation. A number of open documents are used increasingly by teachers, especially slides and films.

PROBLEMS SPECIFIC TO CERTAIN LEVELS

Biology at primary level

Objectives

More than at other levels, biology must be closely integrated to general education: contributing to the awakening of the child's interests, facilitating his incorporation into society, ensuring the balance between feeling and rational thought, contributing to the learning of methods of work. At the same time, scientific activities should help the learning of supporting disciplines (written language and mathematics).

The form in which biology is introduced into the study plans

Biology as such does not necessarily appear on the school timetables. Whenever a school activity bears on a situation involving living things and leads, at least incidentally, to scientific explanation, it is regarded as an introduction to biology, even when the exercise is primarily directed towards other objectives. The place of biology, in study plans can take various forms:

– In some countries, the German Democratic Republic, for example, the elementary school is devoted solely to fundamental learning skills. Yet the practical skills (gardening, for example) allow for the development of an experience common to all children which can later be used in biology.
– In other countries (India, Afghanistan, Tunisia, USSR), the accent is laid on practical objectives (hygiene, agriculture, environmental protection).
– In many recent projects, biology is part of scientific instruction, which is directed towards methodological objectives and eventually towards the learning of basic concepts. The advances are centred on the solution to a problem and aim at developing, in the first place, a scientific attitude (ASS, ESS, SCIS, COPES, BSCS, Nuffield J.Sc., Science 5/13, APSP, and its adaptations to 20 countries in Africa, Indonesia, Japan, Philippines, New Guinea, '*Activites d' eveil*' in France). Whatever they may be called, one can classify them under the heading 'integrated teaching of the natural sciences'.

- Integration extends to the human sciences in a certain number of projects entitled *'Study of the environment'* (most French-speaking countries of western Africa) or *'Environmental study'* (Burma). These projects were first inspired by the concern to prepare for rural extension work and to ensure the cohesion of the nation, but in their content they go beyond the concern for social integration and place the accent on the development of rational thought, which implies access to scientific thought defined by precise methodological and conceptual objectives; a requirement that is not opposed to the concern for the global view.
- Certain study plans (Scientific awareness activities in France, 'Activites d'eveil') have advocated the removal of the frontiers between the disciplines in order to give priority to general educational objectives. But it has appeared categorically in the course of the last few years that general objectives can only be achieved for subjects taken in the living environment of the child if certain objectives specific to biology are achieved at the same time.

The scientific timetable has a very variable place in the weekly schedule (5 to 15 per cent of the total hours in the 4th to the 6th year for Asian countries); the part devoted to biology is rarely specified.

Finally, the following convergent points may be noted in different study plans:

- The desire to give priority to general educational objectives has led to the advocacy of an active method centred on the solution to problems extracted if possible from the environment; the practical objectives and knowledge are seen as spin-offs from this approach.
- Biology appears more and more within the framework of open (non-sectorial) education. Pedagogy tailored according to objectives makes it possible to reconcile two demands which were for long considered incompatible. A flexible school organization permitting a global approach to a problem, an adaptation of the lesson to the interests of the pupils and the effective achievement of a biology training defined by teaching precise skills susceptible to evaluation.

Introduction to biology and associated learning skills: reading, writing and mathematics

Teachers often hesitate to teach biology in the primary schools, as they are afraid of not having enough time for other learning skills which are considered fundamental, especially when selection takes place at the end of this cycle. Such an opinion is now considered erroneous when scientific initiation is conducted according to recent methods. Biological activities performed according to the discovery method are based on communication and rely on oral and written language. Scientific thought demands a high language level and relies on written exercises. Some children who are reluctant to accept the verbal and formal character of the school exercises thus discover that these learning skills have a significance. They promote reading and, as an example, books on nature are much in demand in school libraries. The revision of mathematics teaching goes along with the development of scientific activities, as the building up and the strengthening of the concepts of modern mathematics include analysis of diverse experimental situations.

In some African and Asian countries, and in some European regions, the written language taught in school differs from the language spoken in the home environment. Scientific thought cannot do without the support of the written language, but equally it cannot do without the gathering of data in the environment through the spoken language. During the scientific exercise, therefore, the progressive elaboration of data leads to a change of language. In order to bring about this transposition effectively, several French-speaking western African countries have postponed the beginning of scientific instruction until the third school year.

During the last decade, introduction to biology at the elementary level has acquired a new look. Not only does it bring keys which furnish a better understanding of man in his environment, but it emerges as one of the bridges which enable linguistic and mathematical learning skills to be incorporated in the life activities of children (explorations, physical exercises, rearing

of living beings, technical activities). However, this is only possible if the teacher is capable of directing the spontaneous activities of the children towards an analytical and reflective effort which allows the mastery of educational objectives.

Junior-level secondary education

The problems peculiar to biology teaching for this age group differ greatly from one country to another and according to the channels pupils follow when these are distinct. Do the children follow an instructional course involving a general culture common to all, or are they orientated into separate sections or channels, having different study plans? Do these pupils follow a long curriculum, or are they prepared within a shorter period for a practical skill?

Scientific instruction occupies from 2 to 6 hours and represents an average of 10 to 12 per cent of the weekly timetable. The hours devoted to biology seem to represent 40 to 50 per cent of the total.

Contribution of biology to the achievement of the general objectives of junior-level secondary education

The specific objectives of biology already analysed cannot by themselves determine the contents of the curricula. The contents and the form of biology education are determined by the aims of the school at this level. This aspect was long neglected but is now of increasing importance in projects.

Contribution of biology to a continuous and progressive orientation. The orientation of pupils destined for extended study is too often reduced to selection on the basis of purely verbal criteria or in part on their performance in mathematics. Biology can help towards an orientation based on positive criteria. Instruction in this discipline on the basis of active methods makes it possible to bring out the importance of the qualities of observation, critical judgment, creative imagination, initiative, self-confidence, and mastery of logical thought in exercises which are not purely verbal. Often teachers experience difficulty in objectively distinguishing these abilities. Modern research aims at perfecting indicator grids in order to assist teachers (Progress in science learning; pilot secondary schools in France).

Establishing conditions which facilitate training. After the compulsory period of schooling, biological information in a systematic form is given only to a small number of specialists. For the greater number, further education is limited to information conveyed by the press and the other mass-media. How is this flow of information to be critically received and compared with personal experience so as to reorganize the conceptual network? It is not enough to master the techniques of information: life-long education is primarily of benefit to those who have mastered experimental thought and who have organized their knowledge within a structure.

A great number of projects (CESIP, BSCS, Kiel) try to adapt to the needs of pre-adolescents and answer their everyday problems by encouraging discussions stemming from an objective analysis of the data (environment, pollution, sexuality, drugs). Effective participation in public activities, which is fundamental in a democracy, not only calls for knowledge, but should also make possible discussions with experts about experimental hypotheses and models.

Contents, methods and mode of integration of the discipline

Should the teaching of biology be adapted to the abilities of the pupils? When different streams exist, the following specifications for biology education may often be observed:

- In the long-study streams, teaching has a clear conceptual and verbal orientation. In certain countries (Italy) biology (not botany and zoology) teaching has only recently been introduced. There is a tendency to teach scientific disciplines separately.
- In short-study streams, teaching is of a more concrete character (professional orientation).

It is sometimes given in the form of practical rules which leave insufficient opportunity for critical analysis of problems and decision-taking.

A tendency may currently be observed to reduce these differences: in an increasing number of countries, children who attend the junior-level secondary schools are not separated into distinct streams, but in this case individualization of teaching is promoted.

Problems specific to the junior level, concerning contents and methods. Here there is a greater unity of content and method than for the elementary cycle. It must nevertheless be pointed out that certain recent curricula allot an important role to the study of man (IPN Kiel, BSCS) while human biology was often dealt with later on.

Methods. 'It seems that to educate the youngest children, the most important approach is to sharpen their curiosity and their open-mindedness... Subsequently, it will be interesting to bring the pupils together or make them build an organized network of concepts' (Council of Europe). This conception seems to be generally shared in recent curricula, but its achievement assumes that the teachers will be given sufficient help.

Presentation of study plans. There are three types of presentation:

– Certain curricula are limited to an enumeration of study subjects. They are both too restrictive at the level of contents (study of the cat, of the bat, of a flowering plant, etc.) and too vague as regards the objectives to be achieved (methods and basic concepts). They therefore encourage the teaching of factual knowledge.
– Other study plans (e.g. Nuffield projects, the Scottish project of integrated sciences) are presented in the form of modules centred upon a conceptual area, but conceived in such a way as to favour an approach which focusses on the solution of a problem and progressive access to the experimental method. In principle, these modules leave a certain freedom to teachers and pupils. Moreover, they do not always cover the total number of hours devoted to the subject, and therefore allow an optional activity, often in the form of a project. Study plans by module are widespread at this level. The main concern is to link progressive mastery of the experimental method to the acquisition of precise conceptual objectives, while preoccupation with content is much less at the elementary level. Certain teachers, however, regret that the modules prevent them from achieving a free exploration of their environment.
– Certain study plans (Belgium, France) recommend study by themes, with subjects chosen from the environment, as a starting point. Very great freedom is left to the teachers. Only the basic objectives and the areas to be studied are defined in order to avoid overlaps. These study plans fulfil the demands of the discovery method, but their success depends upon two conditions. On the one hand, teachers must have mastered a pedagogy tailored to the objectives so that they are capable of effectively orientating the work of the pupils, and on the other hand, they must work as a team, since the team undertakes part of the organizational work planned by the module writers.

Methods integrating biology. At this level, biology is still taught in the form of a separate science in one-third of the countries. Sometimes it is the only discipline taught in the 6th or 7th year. A growing number of countries have adopted an integrated teaching of the experimental sciences, either following the introduction of physical sciences at this level, or as a result of a renovation of the general science course. The integration is sometimes limited to a co-ordination of concepts instead of favouring a more flexible approach to the problems of the environment and showing the unity of the experimental method through the various approaches. Some countries (Belgium, Denmark) have tried to integrate human and biological sciences at least during the first two years of the cycle.

It is preferable that integration should not end up as poor biology teaching. Integrated teaching can be ensured by a team of teachers working together.

RECOMMENDATIONS

Recommendations on school organization and means

Because of the evolution of educational aims, it is desirable that biological training should take place at all levels, whatever the form in which it is presented in the study plans. It is desirable that at least part of the teaching be done in the form of practical work and that this requirement should be systematically taken into account in plans for equipment of schools.

All children from an urban environment should have some contact with nature in the form of excursion or nature classes and subsequently through management of the school environment.

Recommendations on the elaboration of school curricula and pedagogical research

It is desirable that no study plan should be imposed without pedagogical research and the participation of the teachers; that the curricula should take account of the availability of equipment and of the training of teachers in order to avoid a return to dogmatic teaching. Teachers should closely involved at all stages of pedagogical research. There should be a link between pedagogical experimentation and the training of teachers in order to avoid the rejection when otherwise well conceived projects are published. Pedagogical research must rely on innovation by teachers.

It is desirable that more attention should be paid to the concrete study of classroom situations, to the analysis of obstacles to the dissemination of a project, and to the reactions of teachers and pupils when facing innovations.

It is desirable that study plans should be drawn up in order to ensure the flexibility implied by the discovery method, with a view to allowing adaptation to the local situations, and to facilitate interdisciplinary study. The objectives must not be limited to a declaration of good intentions. It is necessary to express them clearly in relation to the child's development.

It is desirable that the various modes of integrating biology at the different levels be compared so that this integration allows for effective achievement of the objectives of biology.

Recommendations on pedagogical improvement and the training of teachers

It is desirable to encourage the multiplication of pedagogical teams, and to give them an effective role to play in pedagogical innovation, the adaptation of curricula, in-service training, the use and the fabrication of pedagogical aids.

It is desirable to supply teachers with pedagogical aids in a form which will make an appeal to their creativity and critical sense, and which will encourage team decision-taking. The publication of documents concerning the local environment should also be increased.

The training of teachers should be centred on the capacity to solve problems, to grasp the interaction of biological and social factors in the environment and to develop the analysis of pedagogical relationships by referring to the precise objectives of biology which should not be confined to a mere discourse or lecture.

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The development and design of new courses in secondary biological education

The last fifteen years or so have seen an unprecedented production of new courses in school biology throughout the world as part of a process of educational change in which the school curriculum was subject to a wideranging variety of systematic innovations. In parallel to, and often closely associated with, reform of subject matter came the introduction of new ways of teaching and learning and new forms of curriculum materials. It is the intensity and variety of innovation that made this period unique and it reflected a considerable change in the philosophy of many people concerned with education.

The basic realignment of thought was the acceptance that radical and quick change was needed. Syllabuses and teaching and learning methods were seen as out-of-date, irrelevant and inefficient. Coupled to this was acceptance of the fact that the curriculum would need to be subjected to continuous change as, for example, scientific knowledge and social needs altered. This sense of urgency was tempered by a desire to ensure that innovations were of adequate quality and, for this, systems of organized and evaluated curriculum development were established, usually on a national scale. The curriculum development projects are the most obvious examples of these, but developments within the normal structures of education systems, for example those initiated by examination bodies, also reflected this concern, as did the setting up of special curriculum development units in ministries, of education universities and other inst-

itutions. Towards the end of the period, an additional concern can be detected: the degree to which an education system and the people in it can cope with the demands of extensive innovation. Problems concerned with the implementation of innovation are gaining greater significance. In particular, it is being suggested that teachers should play a more central role in curriculum innovation.

IMPORTED INNOVATION

Although unique social, economic and scientific factors within individual countries have influenced developments in this period, few of the biology courses produced can be said to be genuinely endemic. Many of the ideas and even materials found in most of the new courses have been imported from a few countries such as the United States, the United Kingdom, France and the USSR. As regards secondary biological education, the greatest influence has probably been the Biological Sciences Curriculum Study BSCS in the United States (started in 1959). It set a pattern of development and design which has acted as a stimulus to both imitation and reaction in respect of curriculum development in many countries. To date some sixty countries have adapted or are adapting BSCS materials. The same can be said of the Nuffield Biology projects in the United Kingdom (begun in 1962 and now used in some form in a number of countries), and of activities stemming from a few other countries although these mainly post-dated BSCS while most were influenced, in part at least, by BSCS.
The use of such imported curriculum innovations had several advantages:

- at the time it provided ideas and materials which some countries could not produce themselves because of their lack of appropriately training personnel;
- it provided models of new courses which could be used in the training of future curriculum developers;
- it limited the need for curriculum development work in a country and so enabled restricted financial resources to be used for teachers training and other means of disseminating the innovation;
- it reduced the time needed for changing a country's curriculum.

Importing the innovation also had disadvantages:

- a nation's social needs were not always catered for in imported curricula;
- the species and habitats referred to in the courses were frequently inappropriate;
- the level of a course was not always appropriate;
- the cultural mode i.e. the style of language and illustration, and the historical, social and ideological references, of an imported course did not always match that of the user country;
- irrespective of how much a course was adapted, it remained confined within the frame of the original imported model and was seen as someone else's idea.

The extensive use of these foreign courses indicates that the disadvantages were not seen as crucial, mainly because the courses were usually adapted to some extent to meet the special needs of a user country and because the finance and facilities for large-scale indigenous curriculum development were not available. Furthermore, it can be argued that, whatever their inadequacies in detail, the stimulating effect of the innovations was crucial to progress in many countries.

The origins of these innovations in biology curricula, like those in many other subjects, lay in a unique set of social circumstances particularly centred in the 'Western' world. They were co-incident with the scientific progress that followed World War II, and their diffusion occurred when many nations were in an 'emergent' phase characterized by a shift from dependent to independent status as a result of political, ideological, economical, or other social changes of a profound nature. However, this period is now coming to an end, quite clearly, if there is to be diffusion of curriculum innovation on an international scale in the future it will have to be of a

different nature. It will need to relate to the different associations of countries that have evolved in recent years, the greater equality of political status that exists between countries and the independence of their education systems.

FORMS OF INTERNATIONAL[1] CURRICULUM DEVELOPMENT

It is possible to distinguish two main ways in which international activity has been used as regards curriculum development in biology. The first involves developments within individual countries which are assisted by personnel from abroad. This is the case when a foreign course is adapted for use in a country. Invariably national personnel are sent abroad for training and consultants from other countries are used to assist the work of development. Israel is an example of a country with considerable experience of adapting foreign courses in biology and allied subjects. In countries such as Thailand and Sri Lanka, a similar procedure has been used to develop indigenous biology courses.

The second form of international activity involves several countries participating on the basis of an equal commitment. For example, regional groups of countries have produced 'model' courses or materials which are intended to act as a guide for future curriculum development in the participating countries. The Unesco Pilot project for the improvement of biology teaching in Africa was of this nature. The project had three phases. The first involved the formation of national study groups in each of the participating countries in order to determine their needs in biological education. The second phase commenced in 1967 and involved participants from most of the English-speaking African countries. They were based for ten months at Cape Coast in Ghana. With the assistance of consultants with experience in curriculum development and in biological research and its applications, the team designed a biology course for the lower secondary school and produced pupils' texts, teachers' guides and visual aids for the course. The third phase also took one year but was organized somewhat differently. It consisted of four two-month workshops in the Ivory Coast, Madagascar, Morocco and Cameroon, each involving a different group of participants from French speaking African countries and also consultants. Resource books for teachers and visual aids were prepared, covering topics - tropical ecology, plant physiology, human biology and conservation - appropriate to the later years of secondary education. The materials produced by the project have been made available in both French and English and distributed to African countries and elsewhere. In a few countries, the materials have been used directly in some of the schools but, more typically, they have contributed to indigenous developments by producing ideas and models for the design of courses and materials. At the same time, the participants in the project acquired considerable experience in curriculum development and, on returning to their own countries, were able to contribute expertise to national developments.

The more recent pilot project for biology teaching initiated by the Arab League Educational, Cultural and Scientific Organization (ALECSO) has similar objectives as the Unesco project but has based its work on a series of short (1-2 weeks) workshops at which participants from Arab countries, with the help of consultants from other countries, have established guidelines for courses. Pupils' texts and teachers' guides are written by the participants about their own countries and scrutinized at subsequent ALECSO meetings. The course materials are then distributed to the contributing countries to be used on an experimental basis and adapted to local resources and conditions.

1. *Local* refers to a group of neighbouring schools and their immediate surroundings. *Area* refers to a large portion of a country with relatively uniform social and environmental conditions. The term *national* refers to the whole of a country. *International* refers to any association of two or more countries. *Regional* refers to a group of countries which are geographically close and usually similar in their political, social or environmental characteristics.

In East Africa there has been a third variation of this co-operative mode of development. The three countries, Kenya, Uganda and Tanzania, with support from the Centre for Educational Development Overseas in the United Kingdom have contributed jointly to the development of a secondary biology course by each taking responsibility for an age group. Tanzania was concerned with the early secondary years, the other countries with courses for the older pupils. Joint planning meetings were held but the development of each part of the course was confined to a single country. The completed materials of one country were distributed to the other two for experimental use and adoption.

The virtues of regional co-operation in curriculum development are that:

- it avoids undue duplication of national efforts and enables limited resources of expertise to be more widely used; at the same time it enables each country to contribute directly to the developments;
- the careful scrutiny of ideas and materials by the internation team can provide a means of enhancing the quality of the work;
- the participants in a regional project can also play a significant role in the subsequent implementation of courses in their own countries by conducting in-service courses for teachers and other activities.

Such regional activities have also taken place in the West Indies, South America, Asia and other areas. In some regions, co-operation between countries has resulted from their sharing a common examination system as is the case with the West African countries of Ghana, Nigeria, Sierra Leone and Gambia.

There appears to have been little study of the effectiveness of regional co-operative activities in curriculum development and a balanced appraisal of time would be most valuable for future planning. It is likely, however, that the most important factor for success is the level of commitment for participation by individual countries which requires that they have similar social, political and environmental characteristics, and consequently similar educational needs and objectives. There must also be adequate support for the subsequent adaptation of the course to meet more specific national, area and local needs, and for the day-to-day use of the courses in the schools of the participating countries. With these provisos, there is little doubt that in many parts of the world regional curriculum development has made and can still make a significant contribution to progress.

DEVELOPMENT AND IMPLEMENTATION[1]

In most countries that have undertaken curriculum development in the period under review the emphasis has been on large-scale changes aiming to reform complete courses covering a year or more of school life, the introduction of each new course being a unique event. The model of curriculum development employed was that which is usually referred to as the *centre-periphery* type. Courses were developed by a relatively small, select group of 'experts' (at the 'centre') and disseminated to the schools (at the 'periphery') where they were expected to be implemented faithfully. This model was adopted by most of the curriculum development projects established on a temporary basis and is also typically used by the permanent curriculum development units found in some countries, and by examination bodies which innovate through changing syllabuses and examinations and subsequently provoking the development of new textbooks, equipment etc., by commercial or governmental suppliers.

Frequently the work was based on a research, development and diffusion (R, D and D) model of curriculum innovation involving a systematic and centrally-planned series of pilot studies, field testing and evaluation followed by dissemination. This was particularly the case with the curriculum development projects.

1. See the chapter on 'Curriculum evaluation and dissemination.'

In a number of countries with experience of using these models for development, there has latterly been a growing awareness that while their use can improve the quality of the objectives of a course and the curriculum materials to be used in it, they do not necessarily result in improved practice in schools. A teacher's lack of commitment can result in the inadequate implementation of a course and this can be aggravated by deficiencies in in-service training and other aspects of dissemination. It is argued that because the circumstances of schools are highly variable and teachers' teaching tactics and style are so individualized, it is not possible for a centrally produced course to cater for the range of circumstances in which the materials will be used. There are also misgivings because the R, D and D mode of development has resulted in much slower innovation than anticipated (for example, it has often taken at least five years before materials are available outside the trial schools) and it appears to be unable to respond to continuous change and a variety of needs. Whilst it may be true that in the 1960s biological education was so out-of-date that large scale reform was needed, today a continuous process of development responsive to small, but frequent, change is considered to be more appropriate.

Such reactions to the curriculum development of the 1960s has led to proposals and some activity concerned with local-based and school-based forms of curriculum development, coupled with the provision of a variety of support systems, such as participatory workshops, expert consultants (change agents) and resource centres.

The teacher and development

Curriculum development is essentially a transaction between those that develop a unit of the curriculum and the teachers who implement it. There are thus two basic models of curriculum development.

- when developers and implementers are different groups of people (specialist development);
- when developers and implementers are the same people (teacher development).

In the first model, developers require support in terms of expertise, time and facilities for publishing, equipment construction etc. The teachers require support in terms of communication (dissemination) and training related to the innovation, together with provision of the new materials they need to use. In the second model, the need for dissemination and training is eliminated but more people require support for development and it assumes that teachers have the ability and experience required for development work.

The concept of teacher development does not imply that a teacher works in isolation. Whilst it has individualistic aspects enabling each teacher to meet his or her own unique requirements (which is inevitable whatever mode of curriculum development is utilized) essentially teacher development is envisaged as an interactive and co-operative process in which group activities are predominant.

Whether or not there is any economic advantage for either model has yet to be determined. It is usually assumed that the specialist development model is cheaper but, in fact, experience in several countries suggests that the dissemination and in-service training required to support it adequately is far more costly than was anticipated. A reasonable hypothesis is that modes of teacher development could be devised which, in terms of cost-efficiency, are no less economical than specialist development.

Whether or not there is more expenditure of a teacher's time in teacher development work compared with that necessary for the in-service training, etc., required for the adequate implementation of specialist development is also open to debate. Again it is not unreasonable to suggest that teacher development is no less economical. If a country has a severe teacher shortage it is likely that teacher development and specialist development will be equally difficult.

The value of teacher development can be queried on the grounds that the particular professional expertise of publishers, artists, etc., is essential to prepare adequate curriculum materials and that such expertise is probably not possessed by a substantial number of teachers. This,

of course, is likely to be true for the production of films and other specialized materials, but for biology courses, teacher-produced materials such as work sheets, preparations and collections of local organisms related to the environment can not only be adequate but more relevant. There is thus a great deal of development that teachers will be capable of undertaking. Furthermore the activity of development by teachers adds to their self-education and can have a more general beneficial influence on their teaching.

Teacher development requires that sufficient training in the methodology of curriculum development takes place in pre-service teacher education and that development work is accepted as part of a teacher's professional role (see the chapter on 'Developments in the training and retraining of school biology teachers').

Two strategies of teacher development are offered here for discussion. Others could be suggested.

Self-contained development involves teachers fully in the curriculum development process of devising materials and teaching and learning strategies, trying them out and producing effective products. The work could be undertaken co-operatively by groups of teachers with similar needs and based on a curriculum resource unit in a large school or a local teachers' centre. This would provide the teachers with the physical resources and ancillary help required for producing worksheets, audio-visual aids, collections of organisms, etc.

This strategy assumes a relatively high level of competence on the part of the teachers but it can be a form of self-education in which the teachers learn by doing. It can develop a real sense of professional achievement among teachers.

Supported development requires that teachers be responsible for devising teaching and learning strategies but only outlines and drafts of materials. They work as individuals or in groups depending on their needs and the topic being developed. A local curriculum resource unit would not be required since the teachers meet in schools. However, their drafts and outlines are sent to area resource centres where teams of people with expertise in educational design and the production of curriculum materials produce the final materials for the local teachers.

This strategy does not assume a high level of competence in curriculum development on the part of the teacher and, in fact, has been employed by some curriculum development projects. Its success depends on the area experts having close contact with schools.

Support for teacher development

The *physical facilities* required for teacher development are similar to, though not necessarily as sophisticated as, those used in curriculum development projects. Essentially they should cover reprography (printing and typing, duplicating, etc.), illustration (graphics, audio-visual aids, etc.), laboratory and workshop (for the production of equipment, models, microscopical preparation etc.) and the supply or organisms. These facilities can be based at an area resource centre, a teachers' centre or shared among local schools. In the latter case, teachers in a school can specialize in the provision and use of one of the facilities: for example, one school could be responsible for illustration, another for supply organisms and so on. In this way facilities and expertise can be shared. Technical and secretarial help is essential.

A second resource required is an *ideas-bank*. This would include files of exercises for classwork, technical data for chemicals, equipment, test questions and answers etc. An ideas bank can be built up over a period of time. However, it needs to be organized systematically with an effective, but not necessarily sophisticated, storage and retrieval system.

Where teacher development has been introduced it has proved valuable to have itinerant personnel, sometimes collectively termed *'change-agents'*, who feed ideas from one teacher (or group of teachers) to another, pick up and pass on ideas from a variety of other sources such as specialist journals, universities and international bodies, and informally stimulate the

development activities of teachers and, where necessary, deal with bureaucratic and other obstacles they encounter. The value of change agents depends very much on their personal qualities. In some countries advisers or inspectors and staff in colleges of education and universities act in this capacity and, in a few cases, teachers act as part-time change agents. Personnel attached to teachers' centres or area resource centres may also be used. Experience suggests that to be effective a change agent should not be too closely linked with either educational authority or a formal administrative structure. It is probably best that these change-agents be on temporary appointment so as to make it easier to employ new people in order to introduce new ideas and regenerate enthusiasm. Change-agents can provide a link between educational research and other expertise and the teachers. Whether or not they should monitor teacher development and thus act in an inspectorial capacity is open to question. Possibly this is best done by people more closely linked to the educational administration. Change-agents have been found to be important for the effective dissemination of centrally produced curriculum innovation and, thus, in many countries the introduction of teacher development would merely mean a reorientation of the work of advisers, teacher leaders etc., rather than the formation of a new cadre of change-agents.

Teacher development and national examinations

Whether or not adequate teacher development can occur in a system dominated by highly structured examinations is doubtful. However, the experience of the Certificate of Secondary Education system in the United Kingdom suggests that it is possible to combine a system of national or area examinations with teacher development. (see the chapter on 'Trends in techniques and criteria used in assessing student achievement').

Three modes of examination are offered. For Mode 1 the syllabus and examination is set externally by the Examination Board. However, in Mode 2 the syllabus is determined by the school while the Board does the examining, and in Mode 3 a school is responsible for both the syllabus and the examination for which the Board acts as a moderator. Mode 2 and 3 thus offer considerable opportunity for teacher development.

Teachers' professional organizations

In many countries, organizations of science and/or biology teachers offer facilities through their meetings and journals (and sometimes through their links with national or regional curriculum bodies) for disseminating information about biological education and enable teachers to play a part in formulating policies concerned with their teaching. With teacher development these activities would be more directly valuable to teachers and could be extended. The organizations can also act in co-ordinating and possibly monitoring roles.

Experimental schools

In some countries a small number of schools have been nominated as experimental schools in which curriculum development takes place. Sometimes professional curriculum developers are employed but essentially it is a form of teacher development and it is argued that this form can combine the advantages of teacher development and those of a curriculum development project. Thus it is economical of resources, both manpower and physical facilities. It also allows a high level of radical but controlled innovation to take place without the danger of any errors affecting a large population of pupils. However, there are disadvantages. An experimental school has typical conditions in that it is treated in a special way and inevitably has additional resources. Thus the transfer of an innovation from an experimental to a normal school can present diffi-

culties. When a few schools are designated as experimental this can remove the incentive for innovation from other schools. In several countries there is evidence that experimental schools tend to become isolated and dissemination of innovation from them to other schools is inadequate.

Teacher development and out-of-school resources

An interesting feature of curriculum development in some countries is the combination of teacher development with local activities. Innovation involving work in zoos, botanical gardens, health centres, farms, conservation areas, etc., has added a valuable and particularly relevant element to biological education. For this teachers work with personnel in other areas in designing materials and activities for pupils. Where relevant, parallel or linked schemes with adult or parent education can also be of value. Seen in its full context, teacher development implies a greater realisation of the potential of the individual teacher and a more intense use of educational and community resources. It offers a means of establishing and extending the degree of collaboration between biology teachers and other people from a variety of backgrounds and with a variety of interests. This can be of value in broadening the perspectives through which teachers view their work and also in raising the teachers' professional standing.

Some reservations

In discussing the arguments for teacher-based curriculum development it is important not to ignore the fact that centre-periphery modes of development have some relative advantages for biological education. They can offer a more controlled use of expertise which is particularly valuable when resources are limited. For topics such as metabolism and genetics, which are only affected minimally by local situations, school-based or local development could be wasteful effort, expertise and facilities and the centre-periphery model of curriculum development is possibly more appropriate. This is in contrast to the development of studies involving local environments - in ecology, health and agriculture for example - which are best undertaken locally. For those, teacher development is highly appropriate.

With centralized development, systematic evaluation and monitoring is easier. It is also possible to acquire relative homogeneity in the content and standards of courses which enables pupils to move from one school to another with little difficulty.

Bearing these points in mind it would seem that a country would be best served by:

- The establishment of facilities for teacher development organized in areas so as to foster the involvement of teachers, to strengthen their capacities in this work and to promote the evolution of appropriate curricula and curriculum materials;
- a national body for co-ordinating and monitoring teacher development and initiating national development projects when they are relevant.

The impetus for reform

No method of curriculum development can be effective unless it is supported by the motivation of those taking part. Reference has already been made to the considerable impetus of the curriculum reforms of the 1960s. This was probably one of their most significant features and certainly one of profound value. This impetus came in part from the particular social circumstances of the time but, in addition, it is possible to detect in some of the more successful activities two important influences which need to be considered in discussion about future curriculum development. The first was a willingness on the part of the people taking part to challenge assumptions. This led to the recognition that pupils and teachers had greater capabilities than they were given

credit for previously. The second was their willingness to assume a leadership role and to try out new ideas on an empirical basis. There was faith in the possibility of improvement.

In recent years, curriculum development policies have tended to emphasise contraints such as lack of facilities, ineffective teaching and the low ability of pupils. And there appears to be less faith in the possibility of improvement.

A central problem today in many countries is whether the impetus of leadership in curriculum development can be obtained within the frameworks of restraint that have been established. It points to the central task of those concerned with determining strategies of curriculum development. This is to identify teachers and other personnel who have the capacity to provide the leadership required and to encourage them to overcome the constraints, both real and imaginery, they will face.

Biology, education and society

One of the features of developments in secondary biological education in many countries in the 1960s was the major - and often very effective - part played by research biologists with little experience of school teaching. It has been argued that this resulted in a depreciation of the role of those who were employed in the school system, particularly teachers. In only a few countries, such as the United Kingdom, were teachers dominant participants in curriculum development in the 1960s. Subsequently the situation has been somewhat reversed; curriculum personnel in ministries of education, university departments of education, colleges of education and similar institutions now appear to be dominant. Biologists no longer have such a strong influence and the role of the teacher in development is still being worked out. As far as we can gather, it is rare in most countries for the content of biological education to be discussed by people other than educationalists and biologists even though, of course, its implications for society as a whole are considerable.

Such descriptions do not apply to all countries, but certainly there is sufficient evidence to suggest that in most it has not been possible to produce effective co-operation between groups of people representing the three obvious major influences of relevance to biological education - biology, education (including teachers) and society. This remains a central issue in curriculum development.

The three components should be represented in the committees which determine the objectives and content of biological education. There should be more advanced training programmes in order to produce effective leadership in biological education by people with a combined expertise in the three areas.

THE PACE OF CHANGE

For the next issue, it is salutory to recall a quotation frequently used to portray the dramatic sense of urgency in the developments of the 1960s.

'At the present tempo of research in the Western World, I would estimate the duration of a revisionary cycle in a median science to be of the order of fifteen years. Thus, a body of knowledge acquired in the conventional way by a graduate of 1960 is likely to be largely inadequate by 1968 and, by 1975, as obsolete as notions of body humors, the ether or the impenetrable atom' (Schwab, 1961).

In fact, of course, we were wrong in our estimates of the pace of scientific change relevant to education that would occur. Here we are in 1975 and scientific biology learnt in 1960 is by no means obsolete. Paradoxically, we were also in error in that we failed to anticipate the extent to which educational and social change would provoke future curriculum innovation in biological education. For example, the trend in several countries towards longer schooling and more com-

prehensive forms of school organization have stimulated new ideas about the design of courses with an emphasis on more individualized learning methods, which now have to be considered. It was only in the later stages of the period that the growing social relevance of biological phenomena, especially those of human biology, was adequately recognized.

Whilst we were wrong in our predictions of the type of change that would affect biological education, we were right in predicting that change *per se* would occur and, quite clearly, there are lessons we can learn from this. First, that we should be more cautious in predicting the nature of future changes and, second, that if biological education is to keep pace with the changes that do occur there is a need to establish effective systems for monitoring scientific and social change and disseminating the information quickly and effectively to curriculum developers, including teachers.

We might also add two warnings. The first is that we should not assume that because the pace of scientific change was less in the past fifteen years than we expected, it will not quicken in the future. In fact, the potential in biological research is still immense, particularly in such fields as reproductive and developmental biology, molecular biology, behaviour, ecology and biotechnology. Furthermore, from time to time, there is the need to recycle scientific knowledge in education. For example, in the last two decades, we have tended to depreciate the value of taxonomy in biology courses because of the apparent greater relevance of other topics. However, now that such topics as conservation have become prominent taxonomy has acquired a new relevance.

The second warning centres on the fact that the education a child recieves at school must, to some extent at least, serve him in adult life. During the time he has grown up, however, there will no doubt have been changes which will render at least some of his knowledge obsolete. It is thus important that at the secondary level, there should be a broad, rather than a specialized, coverage of the field of biology. Furthermore, we should try to avoid introducing changes in the curriculum which reflect merely temporary interests, whether they be scientific or social.

Content, process and attitudes

Changes in the content of biology courses over the past decade or so have shown a remarkable similarity in many countries. Whilst the extent of change has varied it has tended to include such aspects as:

- a reduction in the amount of morphological and taxonomic detail;
- a greater emphasis on biochemistry, molecular biology, behaviour and ecology;
- the inclusion of more mathematical topics, and the introduction of topics, such as genetics, to a wider audience and often at an earlier age than was previously felt appropriate.

Possibly one reason why so much of the content of the new biology courses was similar was the tendency to treat biology in the same way as the physical sciences in emphasising those topics which were universal in character. The structure and properties of chemical, atomic theory and the laws of thermodynamics, for example, are the same throughout the world. This is also true for some biological topics such as photosynthesis and respiration dealt with at the biochemical level, but even with these there is great variation in the structure and function of the organs of plants and animals which are involved in these two processes. With environmentally related topics in ecology, for example, the variation from one area of the globe to another is considerable.

More recently there are signs that we are recognizing the variety in biological phenomena and hence the appropriateness of a greater variety in biological syllabuses.

The social needs of individual countries are also receiving more attention. This is shown by the introduction of environmental topics into courses and the relating of courses to the nature of social, economic and scientific developments in a country. Thus, biochemistry is seen to be of value and interest in the schools of those nations with extensive food and other 'biochemical' industries while taxonomy is considered more relevant where the native flora and fauna have yet

to be studied adequately, and rural biology where agriculture is of prime importance. Also, in recent years, the broader links of biology with the psychological, behavioural and social sciences, have been acknowledged and added to those with the physical sciences. Environmental topics and those of human and social biology are now seen as deserving a comparable status in biological curricula with biochemical and physiological topics.

A further trend which has affected both the content of courses and the processes of study involved has been an emphasis on conveying the methodology of scientific research to students. This has included changes in content when, for example, aspects of the history of biology have been introduced; the inclusion of investigatory activities, both intellectual and practical; and the advocacy of more open and permissive teaching and learning styles which aim to stimulate critical thinking, enquiring attitudes and interest. In more recent years this enquiry mode of study has been extended to embrace both scientific enquiry and the forms of problem-solving, used in considering health, environmental, population and similar biosocial topics which involve a high level of value judgement (including ethics), probabilistic assessment and the consideration of priorities in decision-making.

At the same time, paradoxically, the nature of scientific enquiry reflected in the 'new' courses has come under criticism on two grounds. Firstly, it is argued that it depicts a too formal and logical view of science and does not sufficiently emphasise the creative, intuitive and pragmatic aspects of scientific discovery. Secondly, the courses are criticized because they stress the form of enquiry utilized in the physical sciences and depreciate the type of thinking related particularly to social, behavioural and evolutionary studies where the controlled experiment is less appropriate, the phenomena are more complex and questions about function, origin and development are of a different order.

At this stage then, the idea of enquiry teaching and learning is under close scrutiny. It is linked to proposals for devising courses - and some developments - which deliberately set out to change the attitudes of pupils. To some extent all courses do this implicitly but until recently this was not seen as something appropriate for deliberate action, usually because the task was considered to be too difficult, irrelevant, or because of sensitive ethical and political issues. Nevertheless, with the broadening social relevance of biological study, this is a matter that must be of major concern for future curriculum development, particularly in relation to topics such as race, population control, sex, health, conservation and agriculture. It also relates to the image of biology as a whole. Is biology now seen too much as an intellectual science and too little as an activity in which it is respectable 'to get your hands dirty'?

It is important to note that, almost invariably, the introduction of new modes of enquiry into courses in schools has been considerably more difficult to accomplish then changes in subject matter. The careful analysis of what is meant by enquiry teaching and research into methods of undertaking it are still major requirements of biological education.

The task of curriculum development in biological education today is much more complex than it was fifteen years ago and its scope has broadened immensely. There is a dual necessity: to change the nature of biology courses by incorporating a greater breadth of content and approach and, in addition, to acquire more time in the school timetable for it.

Course structure

There was a further inadequacy in our attempts in the 1960s to look into the future of biological education: behind many ideas was the implicit assumption that biology changed uniformly. In reality, there are areas of scientific biology and the personal and social aspects of the subject which are well-established and unlikely to change to any great degree. The basic elements of elementary human biology are a case in point. This contrasts with topics, which have previously been referred to, where in the future change appears to be inevitable.

A major task is to distinguish the conservative (unchanging) and ephemeral (changing)

elements of the biological curriculum. For the former, curriculum development can be more consolidatory, emphasising research into effective teaching and learning methods. For the latter, it will need to be more pragmatic. If we push this scrutiny even further, we can perceive the need to make other distinctions between the elements of biological education, to distinguish, for example, between those elements of direct value to pupils as individuals, those of value to the citizen and those required for future biology-related occupations. This analysis was undertaken to a certain extent in connexion with course developments in the past and a particular feature was the conclusion that, at the secondary-school level, there was little difference between the needs of future biologists and other students. However, rarely was the analysis extended to cover a programme for the complete length of school life.

If we continue to question the value of curriculum development based on complete courses, as indeed is happening today in several countries, we are also led to consider new course structures. Should a modular structure of small, relatively self-contained units be used? What methods can be used to individualize learning to accommodate the range of ability, experience and interest found among pupils? Should we look outside the school for effective biological study through field centres, museums and zoos and community-based activities? In what ways does biology link to other subjects? There are signs in several countries of a fundamental rethinking about the type of course structure applicable to biological education.

Whatever course structures are considered to be most suitable for biology, a factor which clearly will influence their use is the school timetable. The timetabling of school biology varies throughout the world. It may exist as a course over one or several years. It may be allotted anything from one to ten periods each week. Which arrangements are most suitable? It is unlikely that all are equally appropriate. One arrangement which would seem appropriate but rarely exists is that of block timetabling e.g. three weeks of continuous study. It is used in out-of-school field trips. Could it be used in school time? Subjects such as biology to some extent, require, long-term intensive study. This is especially so with topics in ecology and behaviour which are seasonal, and applies to biological practical work in general. Biology has its own unique demands on the school timetable. At present it is more the case that the requirements of subjects such as languages and mathematics dominate decisions. If progress is to be made in biological education then this domination has to be challenged.

Mode of teaching and learning

The period under review here has seen a great deal of research and innovation concerned with teaching and learning methods. (see the chapter on 'The understanding of the learning process and the effectiveness of teaching methods in the classroom, laboratory and field').

The following table compares the modes of learning and teaching prevalent in the 1950s with those which have been introduced since. The list may not be complete and certainly it would not be appropriate for every country. Furthermore, the methods of the 1950s are by no means ignored in the 1970s; in fact the overall practice of biology teaching in most countries is probably still more like that of the 1950s than the 1970s. Basically, the list illustrates the range of the modes of teaching and learning operating today in biological education.

The obvious conclusion to be drawn from this analysis is that curriculum development in the future has a variety of teaching and learning methods to call upon. It would seem that the question of whether the new methods of the 1970s should supersede those established previously is an unreal one. It is more sensible to ask which of the methods in both lists are appropriate for biology courses and, indeed, to accept that methods devised in the future may be just as worthy of inclusion.

The factors which should determine the balance of teaching and learning methods in a course include:

– The *appropriateness* of methods for particular topics. Thus, for example, problem exercises

Some generalized contrasts between the modes of teaching and learning in biology courses in the 1950s and in the 1970s

Highly structured, coherent courses.	Open, flexible courses.
Linear or cyclical courses.	Modular courses.
Teacher-paced work.	Class-paced work.
Students' work as a class on a specific task.	Students' work as individuals or small groups on a variety of tasks.
Teacher lectures, class listens.	Teacher and class discuss.
Learning by telling.	Learning by doing.
Mainly concerned with theory.	Equally theoretical and practical.
Theoretical and practical work.	Theoretical and practical work.
Exercises in practical work used to confirm information presented in theoretical studies.	Enquiry-based practical work.
Textbook dominant.	Multi-media approach.
–	Use of external learning systems e.g. radio, television and computers.
–	Use of models, games and simulation to develop understanding.
–	Use of problems based on second-hand data.
–	Self-developed activities e.g. project work.

using second-hand data are suitable for dealing with topics where one objection is to develop an understanding of the research involved but where practical work is impossible.

– The need for pupils to be able to *continue studies* out of the classroom or laboratory. In this context the textbook is of value. It is portable, allows learning to be paced by the reader and it can be used at any time. Programmed learning texts are more refined versions of the textbook and have similar values. Newspapers, radio, television and other public media can serve as auxillary learning resources.
– The need for a *variety of approaches* to stimulate the interest of pupils. Pupils vary in the ways they come to understand things and thus, it is useful to provide them with different ways of studying topics.
– The need to relate modes of teaching and learning to the *personality of teachers*. Research and experience indicate that while the introduction of new materials can result in changes of teaching strategies (the outline teaching structure of a course) and teaching tactics (how teachers manage the resources and techniques available to them), teaching style (a person's individual teaching behaviour which reflects their personality and relations with pupils) is merely affected. Thus, it is suggested that the design of course materials and teaching techniques should be flexible enough to harmonize with a variety of teaching styles so as to maximize their beneficial effects.
– The *cost-effectiveness* of the methods. This is most important when expensive equipment is used or the costs of maintenance are high. In most countries the major criteria for judging the value of an expensive new method are whether it achieves its educational purpose

better than comparable cheaper methods and, if it does, whether the achievement of the objectives is worth the price.

Biology in the whole curriculum

Apparently the typical situation in the secondary schools of most countries is for biology to exist as a subject only in the later years and them to be optional. In the early years of secondary education, biological topics are considered within the framework of subjects such as general or integrated science, agriculture, rural studies, environmental science (with emphasis on physical science), environmental studies (related more to geography and social science), health education and social studies. There are also trends - although admittedly slight - towards the introduction of integrated science and broader environmental and social studies in the upper-school with a consequent elimination of biology and towards the introduction of a variety of forms of biology, including human biology and social biology. The expansion of the scope of biological education referred to earlier has taken place at a time when integration of subjects has been seen to have educational advantages. The result is a conflict which clearly requires resolution.

This, then, is the issue which is probably the most fundamental of all those we are concerned with - what should be the function of biology in secondary education, what place should biology occupy in the curriculum as a whole? Obviously, unless this issue is resolved, work in curriculum development and design will lack an adequate framework.

The chapter 'Trends in the purposes and objectives of biological Education' provides detailed consideration of issue. It is one for discussion and the following points are offered for this discussion.

Is biology a single scientific discipline with a coherence of its own, an integral logical structure and a specific methodology?

Is biology an amalgam of a number of related scientific disciplines, such as biochemistry, genetics and ecology, each possessing its own coherent logical structure and specialist methodology but easily related under the heading of a single subject in the curriculum?

Is biology, conceived as the study of life, a theme encompassing a range of subjects, such as the natural and social sciences together with aspects of the humanities, which do not necessarily fit together to form a single coherent whole but can be interrelated into a broad field of knowledge?

A distinction can be drawn between subjects which are an integral part of the field of biological education and those which support it. Chemistry and mathematics are examples of the latter, (physics, incidentally, has a relatively low level of involvement in school biology) and several topics in these subjects are relevant. Should these topics be taken separately or woven into a biology course? A greater degree of curriculum co-ordination in this respect would be valuable. However, it is not easy to ensure that studies of topics common to a variety of subject fields coincide in the school timetable.

Biology is best viewed as a field of study concerned with a comprehensive understanding of the living world including human beings. It should be related to the needs of both society and people as individuals and should recognize the vulnerability of the biosphere. To meet the implications of this broad view adequately, biological education must become a more dominant influence on the school curriculum. It is essential that there be a reappraisal of the balance of subjects in the secondary school timetable to enable this to take place.

SUMMARY RECOMMENDATIONS

In the past, few of the national developments in biology courses were genuinely endemic. They depended on the international diffusion of ideas and materials from certain of the more develop-

ed countries. International diffusion of curriculum innovation can still occur, but it is likely to be more related to developments involving a more equable participation by groups of countries. Regional co-operation in curriculum development has an obvious advantage, particularly for countries with adequate expertise or resources. However, a study should be made of past and current regional co-operative activities in curriculum development in order to provide guidance for more effective future planning.

The centre-periphery and the research, development and diffusion (R, D & D) models of curriculum development have limitations, particularly with respect to the adequate implementation of innovation in schools. Such models cannot meet all of a country's curriculum development needs. The crucial issue in future curriculum development is a reappraisal of the role that teachers should play. Schemes of curriculum development directly involving teachers and related to local or area resource centres should be tried out. A country would probably best be served by the establishment of facilities for schemes of teacher development which would be co-ordinated and monitored by a national body. This body should also have the power to initiate national developments when they are necessary. The professional organizations of science and/or biology teachers have an important role to play in such schemes. Committees determining the objectives and content of biological education rarely contain - but should contain - members with expertise in biological science, education (including teachers), and the requirements of their society.

In the past, predictions of the type of scientific change that would affect biological education were often incorrect. There is a need to establish effective systems for monitoring scientific and social change and disseminating the information quickly and effectively to curriculum developers, including teachers.

The task of biological education today is more complex than in the past and its scope has broadened immensely, involving not only relations with the physical sciences and mathematics but also with the behavioural and social sciences. The enlarged human and social relevance of biology will be a major concern for future curriculum development. It is related to health, environment, nutrition, population and other topics and involves value judgements, aesthetics and ethical considerations as well as scientific methods of study.

At secondary level there should be a broad, rather than a specialized coverage in the field of biology. An analysis of the nature and methods of enquiry teaching relevant to this broadened concept of biology should be a major research commitment for biological education within the context of different cultures and environments.

Another important task is to distinguish between the relatively permanent and the more ephemeral elements of the biological curriculum and to relate future research and development to this.

There is a need to conceive of biological education as a flexible programme of different activities within the school, in the local environment and, where relevant, in situations in other areas. It should cover the whole of a young person's educational life. Investigations are needed into the most suitable course structures for biology within this broad context. In parallel with this is the need to reassess the demands of biology on the school timetable.

Major factors which should determine which teaching and learning methods are used in biology courses include:

- appropriateness of methods for each group of students;
- the need for students to be able to continue studies outside as well as in school;
- the value of approaches for encouraging the interest of students and thus aiding their learning;
- the adaptability of methods to allow for a variety of teaching styles;
- the cost effectiveness of the methods.

School biology is best viewed as a field of study concerned with a comprehensive and integrated understanding of the living world, including human beings. To play its proper role in education, biology should have a much greater influence on the school curriculum.

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Curriculum evaluation and dissemination

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EVALUATION

INTRODUCTION

No teaching exists without evaluation. Evaluation may be implicit and unstructured. It can consist of simply thinking of the most effective way to differentiate between mitosis and meiosis, or deciding which flower will most clearly show stamens and anthers. Everything that is done in the process of teaching is evaluated – consciously or subconsciously – for its effectiveness of information transfer and student comprehension. If a technique works especially well, it is noted for future reference. If it fails to work a second time, it is reconsidered.

A good curriculum developer takes both the subtle and overt feedback of a class, measures how well the goals of the curriculum are being attained, and compensates accordingly. This type of evaluation must have existed since the time of the cavemen, but, more recently, we have gradually moved towards a plan and design for curriculum evaluation that attempts to organize and formalise our measures of curriculum effectiveness, as well as to provide a structure wherein more precise, meaningful, and transferable evaluation data can be collected. Newer works now specifically concern themselves with such structured evaluations (8, 38).[1] Even so, it must be emphasized that structured evaluations are in their infancy, and the usefulness and value of various evaluative techniques are still being debated.

It is not intended to present here *the* method of evaluation, but only the current status of the art and the wide variety of techniques being used. Evaluation will here refer only to those processes related to determining the impact of a curriculum. We will not specifically deal with the assessment of student achievement (see chapter on 'Trends in techniques and criteria used in assessing student achievement'), nor will we cover the system of management of evaluation activities that must accompany any evaluation design.

EVALUATING OBJECTIVES

Evaluation of any kind requires something to measure. This something is currently the educational objective. Is our objective for the student to learn the names of the parts of a crayfish appendage? That can be measured. Is our objective for the student to know the evidence underlying the theory of evolution? That can be measured. Is our objective to teach the student how to think, or how to learn on his own? This involves a more difficult task of evaluation. Is our objective to produce honest, loyal, personable, brave, and reasoning men and women? Here, results are almost impossible to measure because of the many variables and interpretations related to such a broad objective.

[1] Numbers refer to the Bibliography page 99.

Attainment of simple cognitive objectives is easy to measure. The broader and more affective the objectives, however, the more difficult the evaluation. Nevertheless, evaluation must be ready to find ways to establish pupils' 'creative abilities and to devise satisfactory techniques for appraising their whole attitude and personality' (34).

TYPES OF EVALUATION

Internal

Many types of evaluation may be employed. One commonly used is an internal evaluation of the curriculum in terms of the objectives it has set out to achieve (14). This internal measure does not normally question the objectives themselves, but only such data as that the curriculum was able to impart to 70 per cent of the students the names of common birds in a given region. The objectives may be trivial, but their degree of achievement is quantifiable. That type of internal evaluation, normally conducted by testing students with questions that reflect the curriculum's objectives, does give a measure of curriculum effectiveness. But a note of caution must be sounded concerning variables. The same curriculum taught under a wide variety of situations to a broad spectrum of students by a great number of teachers will not produce identical results (37). Variables may include the age of the pupil, the pupil's academic background, training of the teacher in the discipline concerned, the age and experience of the teacher, school facilities, and the time allocated to the course. These and dozens of other factors have been shown to influence the effectiveness of teaching (1). Even the salaries that teachers are paid and their external worries will affect evaluation results. Thus, care must always be exercised to avoid confusing curriculum effectiveness with teacher effectiveness (43), student preparation, or one of a dozen other variables.

One must regard a good course of instruction as one would regard good tools given to a workman. There is an old saying that a poor workman blames his tools. Many times curricula have been changed when an analysis of the situation would have indicated that the curriculum was satisfactory, but other factors had contributed to the poor results. No curriculum, however good, can rectify all the problems of education (13), but every effort must be made to provide the best possible curriculum so that other variables affecting education can be isolated and dealt with. If examinations are the instruments used to measure the attainment of curriculum objectives, then obviously the examinations must incorporate the objectives concerned. For this purpose, it is necessary to prepare a detailed statement of the abilities and content that the objectives demand. Klinckmann (25) reports on such a test analysis, wherein the four cognitive abilities necessary for an understanding of biological sciences were listed as follows: recall of materials previously learned; application of knowledge to new situations; use of skills involved in understanding of scientific problems; and showing of relationships between bodies of knowledge. She further noted that these categories could be broken down into more specific abilities, and that examinations could be ranked for their capacity to measure these devices. Figure 1 shows a test grid that deals with the four ability categories separated according to Bloom's *Taxonomy of Educational Objectives* (5), and with major curriculum themes along the top of the chart. The individual numbers relate to the items on this particular examination that fitted the categories concerned. Note that no one examination could provide questions sufficiently representative of all 234 categories of the grid, nor is such to be expected. The significant factor is that the use of such a grid focuses the attention of those preparing examinations on the necessity to provide a wide variety of questions over a period of time so that at the end of the course the grid would have a minimal number of blank spaces. Only by such a control device can it be ensured that the curriculum is being properly measured for internal consistency with its own objectives. This particular grid was for a specific segment of a course with identifiable themes and cognitive abilities. Other grids could be constructed for courses with different objectives and cognitive

abilities in mind. The emphasis is not on this as an ideal grid, but rather on the grid as a usable model whereby the attainment of curriculum goals can be identified and quantified.

A = Recall and Reorg Matl's Learned
B = Apply Knowldg to New Concrete Situations
C = Use Skills Involved in Udstg Sci Probls
D = Show Relats Bet. Bodies of Knowledge

	Evolution	Div of Type & Unity of Pattern	Gen Continuity	Complem of Org & Environment	Biol Roots of Behavior	Comp of Structure & Function	Homeostasis and Regulation	Intellect History	Science as Enquiry	Sub-category Totals	Major Categ. Totals
A 1-1 Terminology			1	1						2	
1-2 Specific Facts	2		2	1		4	2			11	
2-1 Conventions										0	
2-2 Trends and Sequences			1	1			2			4	
2-3 Classifications and Categories										0	31
2-4 Criteria									1	1	
2-5 Methodology			1							1	
3-1 Principles and Generalizations	1					4				5	
3-2 Theories and Structures	5							2		7	
B 1 Non-quantitative knowledge	1		3	1			2			7	
2 Quantitative materials					2					2	9
C 1-1 Interpret qualitative data	1								3	4	
1-2 Interpret quantitative data	1						1		2	4	
2 Understand relevance of data to probl										0	
3 Screen and judge design of expt's										0	10
4 Screen hypotheses	1								1	2	
5 Identify problems										0	
6 Identify asspt's and prin enquiry										0	
7 Analyze scientific reports										0	
D 1 Comparison										0	
2 Extrapolation										0	
3-1 Application—to another biol area										0	
3-2 Application—to other fields										0	
4 Analysis of relationships										0	0
5 Interrelate facts, prins, etc, in a new way										0	
6 Development of a new set of interrelated concepts										0	
Totals	12	0	8	4	2	8	7	2	7	50	50

Fig.1. Biological sciences curriculum study test grid. This test grid compares themes of a typical biology curriculum with specific pedagogic objectives. It can serve not only to evaluate the breadth of a given examination, but also to evaluate curriculum coverage. The greater the spread of items across the grid, the greater the assurance that cognitive themes are being achieved at a variety of educational difficulty levels.

Cross curriculum

A question frequently asked when a new curriculum or course is introduced into a system is, "How much better is curriculum A than B?" Again, the answer to this question must be sought within the framework of curriculum objectives. Systematists are likely to approve of a curriculum that emphasizes morphology and systematics, while a geneticist would be more favorably inclined toward one that emphasized biochemistry and mathematics. School curricula are not directed either to systematists or geneticists, however, but are broadly designed to give the student as basic an acquaintance with the field as possible. The best mechanism for evaluating which curriculum is "better" is to place each against a previously agreed-upon standard. Each country, each region, each school system, and each teacher ultimately has consequential objectives. The "better" curriculum in every case is the one that most closely allows realization of the previously agreed-upon objectives.

Worldwide educational objectives vary. In some countries education is concerned with the eradication of illiteracy, while in others it may deal with the application of esoteric technologies. Curriculum evaluations must not only consider the individual and apply the maxim that he must be taken from where he is to a more productive plateau, but they must also consider the societal patterns where the education is offered. There is evidence that nations are becoming more concerned with the preparation of indigenous curricula that emphasize social, scientific and humanistic goals of their own societies, and it is in these frameworks that the uniqueness of biology as a science becomes readily apparent (39). In the past, temperate zone curricula were exported to countries throughout the globe and used with little or no change in schools of the tropical as well as the temperate zones. This is not a critical matter for such subjects as mathematics, physics, or chemistry because of their basic universality. But the exportation of curricula is a far more critical matter when dealing with biology. While biology has basic ideas that may be universally applied, such as the cell theory, mitosis, genetics, and evolution, it nonetheless has a strong regional component. It deals with the environment of the individual in a way that neither chemistry, physics, nor mathematics can approach. Flora and fauna of the globe differ markedly, and the biological problems associated with specific biomes are varied indeed.

It is not sufficient to concentrate on robins, oak trees, and birches in the temperate zones of the world and expect students in the tropics to relate to them. In the days of the exported curriculum, no concessions were made in respect of either flora or fauna, or peculiar local biological problems. Students in the tropics studied the daffodil and the spruce tree while surrounded by bamboo and banyan; they studied robins and jaegers in an environment of mynas and secretary birds.

The objectives of such curricula could only be measured by exported examinations, and many times this required the importation of appropriate specimens from the temperate zone to match the syllabus and text the student was studying. In these cases, evaluation measured the ability of the student to master an essentially foreign curriculum without attempting to measure the relevance of the materials so mastered. The situation was such that the students were led subconsciously to believe that biology was something that happened in the United Kingdom, or France, or Germany, or the United States, and that their own environment was either aberrant, or at least nonbiological.

In terms of a 'better' curriculum, therefore, evaluation should attempt to ascertain that the curriculum under investigation properly reflects cultural differences and the differences in the organization of the school system; it should be cognizant of the different aims of the societies concerned, and of the particular developmental state of the region involved. In short, new evaluation instruments are needed that measure the new objectives (28).

Globally, 'better' curricula are being produced through the development of indigenous materials with the primary aim of explicating the student's immediate surroundings, while rejecting imported and nonapplicable materials (40). Not only as the local flora and fauna been incorporated in newly developed regional curricula, but the emphasis on regional problems has increased markedly (10). In order to insure proper regionalization of curriculum content it must be checked by appropriate experts. The temperate zone textbooks largely ignored such health problems as schistosomiasis, yellow fever, and malaria. Basic information about these diseases has now been introduced in appropriate geographic areas so the student may comprehend the health problems of his own region. The agricultural emphasis of indigenous textbooks has likewise been changed. These now stress water economy in desert land, snow in mountainous country, and drainage in areas of plentiful rainfall. These considerations have led to the production of materials for biological education that concern both individuals and their immediate environments. Evaluation of such concerns with respect to agriculture, health, and an interpretation of the regional flora and fauna (3) is a first step in developing materials that largely reflect the objectives of education in a particular area.

'Better' curricula will not only be based on a knowledge of the local flora and fauna, but also on a comprehension of the problems facing a country that biology can help to solve. It is

unfortunate that many professional biologists throughout the world are dealing not with the problems of their own countries, but with problems of the more developed countries. There is a necessity for concentrating research on the problems of a specific region, not only for the growth of that region, but also to provide the requisite materials for its student to use (19). To this end the Science Education Centre of Southern Rhodesia has appointed to good effect a school biology innovator with the task of translating aspects of the work of local biologists which may have particular significance into classroom activities.

The concept of 'better' must also take cognizance of fadi in the biological sciences. It may well be that the current popular concentration on molecular biology, quantitative biology, genetic engineering, and other similar topics does not contribute to the solution of problems in regions where resource books are badly needed on environmental questions and the systematics of local organisms (20).

A 'better' curriculum must be evaluated in terms of the educational objectives set by the educational apparatus of the country concerned. Very broadly speaking, those objectives an evaluator must look to in respect of biology as a discipline fall into five major categories:

Career preparation. This category deals with careers in such fields as medicine, dentistry, teaching, and research, and calls for a specific preparation in biology that is determined largely by the professional school or college the individual is ultimately to enter. No nation can afford to ignore the need to prepare professional biologists for work in environmental preservation, energy conservation, health, and other such basics necessary to its welfare. Evaluation of a 'better' curriculum, therefore, should note the provisions the curriculum makes for preparation of a certain segment of students to pursue professional biological work (9).

Biological application. The primary use of applied biology is in agriculture and fisheries. More emphasis is now being placed on these topics in school biology programmes (4, 33). Here again, the curriculum for persons entering these fields is determined very largely by the agriculture and fishing industry of the country concerned, and these are themselves functions of the environment. Countries that have agricultural monocultures proceed along traditional lines, and educational advances that communicate new techniques or new potential crops must break through a barrier of tradition. These breakthroughs, which evaluation must measure, are more effective in increasing the yield of an already established crop such as rice, where the so-called miracle rice is substituted for rice previously grown, than in attempting to shift the agricultural base from rice, let us say, to wheat or corn. Personnel need to be trained for such breakthroughs by means of a 'better' curriculum that exposes students to a wide variety of techniques and practices used throughout the planet in the production of food. Some of these techniques and practices may ultimately be incorporated into the economy of the country concerned. A properly designed evaluation can measure how well such valuable outcomes are achieved.

Individual Maintenance. Biology has a great deal to contribute to the maintenance of both individuals and their societies, particularly in matters of hygiene and health. 'Better' curricula should emphasize proper nutrition, bodily care, the necessity for certain types of exercise, and should give the individuals an understanding of the operation of their own bodies and the potential deficiences in them. A curriculum dealing with these matters should include health-related materials on drug usage, tobacco, alcohol, and self-diagnostic procedures used to detect early warning signs of cancer and a variety of other diseases (41). This aspect of the "better" curriculum substitutes science for superstition and quackery. Health statistics and surveys provide data by which the contribution of new educational programmes can be evaluated.

Appreciation. Appreciation of the environment and its care is a biological facet which is often ignored. An understanding of a country's biological potential is as important as an understanding of a country's biological situation. Reforestation should never be attempted, for instance, without establishing that the area can support a forest. No large-scale attempts should be made to stock fish in lakes and streams unless it is known that fish once inhabited those waters. For the world of the future, it is necessary to understand that clean air and clear water may be as important as food to the ultimate development of the individual.

Curriculum concerns are beginning to be focused on appreciation as a measurable objective of biology (2). The aesthetic values of a tree, a flower, or a bird, might well be included in developing environmental awareness. In some cultures, as, for example, in Japan, aesthetic appreciation has reached the state of a high art; in others, it may not even be a consideration. Evaluation is difficult in areas of value judgment, but environmental awareness can be measured, and the effect of new curriculum materials on changes in that awareness can be noted.

Problem solving. Biological problems may be either local or global in scope. The closer a biological problem is confined to a specific region, the easier its solution. Some studies indicate that the number of people on the planet will eventually exceed its carrying capacity; but because of the uneven distribution of individuals and natural resources, the population problem is already exacerbated in certain regions. And, while a global approach to the problem may be dictated, the solution is still in the hands of persons who view the problem with a regional bias.

One of the functions of the 'better' biological curriculum is not only to bring problem-solving techniques to students (12), but also to point out problems to those who will be called upon to solve them. No solutions are possible until problems have been perceived. A curriculum that deals with the solution to a problem not known to exist is ineffectual. Evaluation tasks can deal with problem-solving abilities and measure how well various problems are perceived after the students have been exposed to a curriculum designed to emphasize these abilities and perceptions.

Cross-curriculum evaluation can be made, therefore, that will serve to identify a curriculum as one which most effectively prepares the citizens of a region to comprehend its biological problems and to find solutions to them.

Reflective evaluation

Many think of reflective evaluation as the initial part of formative evaluation design, but others regard it as a separate category (7). Reflective evaluation might be defined as a precursor activity that screens curriculum components for suitability. It is subjective for it often involves intuitive insights that may be used to clarify definitions and to refine the criteria for deciding what should be included in a given curriculum. Applying the reflective technique may be aided by a checklist or a rating scale. By identifying crucial questions related to various curriculum components and reflecting upon them against the background of relevant information, the resulting curriculum design may be improved. The value of reflective evaluation is that it forces curriculum developers to think through the curriculum design, using experience and judgment to interpret relevant data, before putting pencil to paper.

Formative evaluation

Curriculum development plans normally provide a period for classroom tryout of experimental materials. During this time the evaluation design is formative in nature. The entire purpose of the formative evaluation is to provide on ongoing evaluation of the many components of the curriculum, and to use the feedback for adjusting both the approaches and the materials (15).

The initial audience for the formative evaluation data is the curriculum development staff and the support source – ministry of education, private foundation, school system, or whatever. Data for these audiences are accumulated through testing of experimental materials in a cross section of schools where they are designed to be used. This means a plan to include the various cultural and geographic regions of a country as well as a cross-section of schools themselves – poor schools, rich schools, public schools, private schools, city schools, suburban schools, and rural schools. Unless the curriculum is designed for a specific target population, the broader the test sample, the more valuable the field test data will be in changing both content and pedagogy to accommodate the largest possible population. Only in the most affluent countries is it possible to prepare curriculum materials for specific population segments; for the most part, curricula are

nationwide in scope and plan. A series of formative evaluations dealing with programmes for the mentally handicapped are examples of evaluative techniques used in curriculum projects for specific population segments (16).

No single evaluative design will measure all of the variables in teaching and learning, but measurement of as many as possible should be attempted. The success of the effort is dependent upon budget, time, personnel, planning, and the type of questions that need to be answered. Unless the purposes of evaluation are focused on project goals, the evaluation may be of little use. The evaluation plan should describe the sources of data, their justification, and the methodology and instruments to be used in accumulating the data. Figure 2 (26) indicates a typical design for data collection. The questions for evaluation have been delineated and the kinds of information necessary to answer the questions are shown in the circles. Means by which the data are gathered are noted in the rectangular boxes on either side. Data can be gathered for formative evaluations at a number of stages; these vary from exploratory studies begun prior to development and carried through to pilot teaching, or field-test studies carried out after completion of the project.

Summative evaluation

Summative evaluation involves the gathering and interpretation of data in order to provide a broad systematic appraisal of a curriculum in operation after it is completed and in use in the schools (6). There is not always a clear-cut differentiation between formative and summative evaluation. Many of the questions related to a formative evaluation continue to be applicable to summative activities. Summative evaluation notes the continuing project need for information on how and when materials work, and identification of their weaknesses and strengths. These data facilitate later revisions of the materials and aid in developing additional materials or programmes and enhancing their use. The longitudinal study – study of the same population over a period of time – can determine how well learnings from a curriculum are retained and used in later years, which is a crucial test for any curriculum.

Responsive evaluation

While formative and summative evaluations are undoubtedly the primary ones used in curriculum development, they are preordinate; that is, they rely on prespecification of goals. There are other ways of looking at evaluation that are not preordinate. One alternative is responsive evaluation (36). Responsive evaluation concerns itself more directly with programme activities than with programme intents; it responds to audience requirements for information and takes cognizance of the different value perspectives present. While proponents of responsive evaluation indicate that it, too, requires planning and structure, they differentiate it from other forms of evaluation by treating objectives, hypotheses, test batteries, syllabuses, and such, as components to be evaluated themselves, not as the basis for an evaluation plan. Certainly preordinate evaluation is to be preferred to responsive evaluation when it is necessary to know if certain goals have been reached, or whether certain hypotheses or issues need to be investigated. Responsive evaluation has the built-in flaw of excess subjectivity. It serves as a more casual, less scientific way of reporting.

Illuminative evaluation

Illuminative evaluation is another device suggested by those who feel that preordinate evaluations should be augmented or replaced by other techniques (32). Illuminative evaluation purports not so much to test as to understand and document an innovation by examining its background, its organization, its practices, and its problems, in addition to its outcomes. It suggests detailed, accurate, and sensitive reporting, organized and ordered, and including interpretative and explanatory comment. Weaknesses of the illuminative evaluation include lack of objectivity, poten-

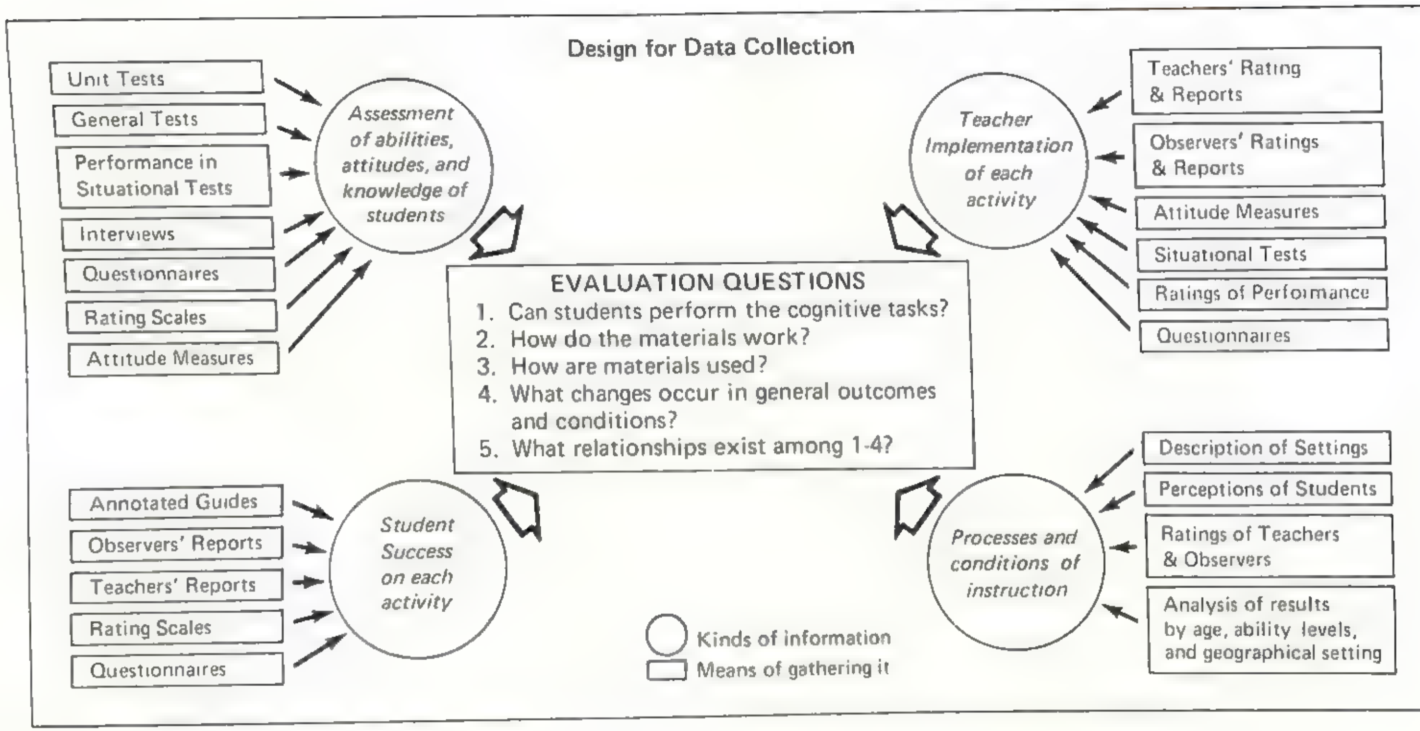

Fig. 2. An evaluation design for data collection. The methods of data gathering are indicated in the rectangles. The circles display the kinds of information to which the data have been designed to contribute and the central block contains the evaluation questions to be answered by these data.

tial research bias, and the use of techniques more applicable to the social than to the natural sciences.

NECESSITY FOR EVALUATING

Evaluative techniques are themselves undergoing change. With the increasing worldwide emphasis on educational accountability, questions are being asked and curricula are being designed to answer them. To be effective, answers require evaluation. Whether evaluation comes from within the project or without is a debatable point, with arguments on both sides. Now more than ever it seems quite unacceptable to introduce change merely for change's sake, or to prepare curricula that are without objectives, that are redundant, and that rely solely on their use to prove their validity. In developing countries in particular, there is a necessity for stressing practical rather than theoretical aspects of development and evaluation. It is difficult enough to induce curricular change, and the opponents of change justifiably criticize the lack of substantiation for it. We see constantly changing curricula in our schools, but only critical curriculum evaluation can determine whether or not we are simply changing curricula without necessarily improving them.

While evaluation is essential, caution must be exercised in interpreting the data. Many more extrapolations have been made from educational data than was warranted by the particular situation described; one must constantly be on the alert in examining evaluative results to ascertain whether there have been proper controls and whether all possible variables have been taken into account or, at least, described. Not only in the experimental design itself but in the treatment of data are some evaluation studies suspect. There have been instances where raw data indicating one thing have been statistically manipulated to indicate exactly the opposite. Unless one is familiar with statistical procedures, conclusions are accepted at face value without adequate investigation of the statistical mechanisms concerned. No single curriculum can take credit for all of a student's knowledge about a topic, yet evaluation studies attempt to measure the student's cognitive achievement of curriculum content through a series of examinations given during the course of that curriculum. The achievement of affective goals is much more difficult to measure, for such goals are tenuous at best and subject to a great deal of interpretation. Evaluation instruments are needed that will truly measure the goals of a curriculum, both cognitive and effective, before sufficient data can be collected to support or disprove many of the claims made for a specific curriculum.

STANDARD EXAMINATIONS AND EVALUATION

Curriculum change and curriculum evaluation are sometimes limited by the standardized or national examinations required in many regions at certain critical stages in the student's educational career. (See chapter on "Trends in techniques and criteria used in assessing student achievement"). Curriculum developers are hampered because the major educational objective becomes one of training students to pass an examination, not of preparing them for life. When such an examination carries so much weight, it creates a closed loop whereby the examination cannot be changed because it measures mastery of the curriculum, and the curriculum cannot be changed because it prepares for the examination. Thus, just as there is a recognised need for curriculum change, so must one recognize the need for examination change. No examination should ever be devised that does not have within its structure a provision for self-destruction, or change. In every case where an examination reflects curriculum content, it becomes almost impossible to change either, for each uses the other as an excuse to maintain the status quo.

With a rigid, fixed examination that supposedly measures the students' learning through use of a curriculum, change is difficult if not impossible to achieve. When examination and curriculum are inextricably bound, both must have provisions for change, and neither must inhibit the growth of the other. Evaluation is a device whereby student progress may be measured. It should not be-

come a device whereby student progress is inhibited because passing a given examination is the major objective of a curriculum.

TRENDS TO EVALUATE

Certain trends can be identified as being worthy of evaluation in the future. The major ones that evaluation needs to be concerned with are as follows.

The desire for change

There is a worldwide dissatisfaction with current curriculum practices that has led to a desire for curriculum change (35) (see the chapter on 'The development and design of new courses in secondary biological education'). Practically every nation, from the most technologically advanced to the most recently emergent, is concerned about current practice and is inquiring about initiating change. If there is one constant an evaluator has to keep in mind, it is this trend toward change. Evaluation can provide data to promote change that is contributory, and not just cosmetic. Evaluation mitigates the tendency to change only for the sake of changing.

Identity

This is the trend where regional and national aims are reached through materials that are readily identifiable with the region or nation concerned (11). Thus, evaluation must take account of the necessity for measuring regional and national identity and goals.

Relevance

In terms of biological content, evaluation is shifting toward a concern for the relevance of the curriculum. By far the largest proportion of individuals who take biology in school will be neither scientists nor biologists. Past practices of teaching biology to all students as if they were planning to become professionals in the field is diminishing. We now recognize that biology first of all must meet the needs of the average citizen, giving each an understanding of the environment and its natural problems. Evaluation must concentrate on whether students can react to questions about the future, as well as questions about the present; it must ensure measurement of issue-oriented or problem-oriented situations, including such topics as reproduction, birth control, pollution, population, aggression, and other concerns of the citizenry.

Evaluation must recognize that we are moving away from biology considered mainly as systematics and morphology and away from the wealth of sometimes useless material that students have been forced to memorize. Now we are asking questions about what segments of biology will be most useful to the development of the individual in the framework of society (30). Perhaps through evaluative techniques we will be more concerned with allowing the citizen to live in harmony with environment. This means that we will be evaluating a more practical, relevant, and less theoretical biology than in the past.

Individual differences

Student variability is a well known fact and, as countries undertake the Herculean task of providing education for every citizen, the problems of accommodating to individual abilities are

becoming predominant. Because no one set of materials is equally applicable to all students, materials are now prepared not only for the average and above-average student, but for students who are consistently academically unsuccessful (42) and, in many cases, for those who are either physically or mentally handicapped. Evaluation designs must take into account the continuing trend for more education to reach more and more people.

Sequence

The placement of a topic such as biology in school syllabuses is receiving considerable attention. The trend is, rather than to place biology at a specific school level, to build an integrated series of experiences at each grade level, from kindergarten through college. Each one is cumulative, and the series as a whole accounts for a total exposure, so that the student does not continually circle over a given subject matter year after year at successively higher vocabularly levels (17). Evaluations must take cognizance of this earlier experience and cumulative exposure to content.

Multimedia

The trend is toward the use of an increasingly wide variety of educational technologies and media to provide maximal sensory inputs on given topics (31; see also the chapter on 'The impact of new instructional equipment and educational technology in the process of teaching biology'). The major drawback to the extensive use of different media has been and will continue to be expense, and the misuse of media must be reduced. Media usage is applicable when the message can most effectively be transmitted through the mechanism of films, television, computer-assisted instruction, and other such devices. Unless there is to be a significant academic gain, the use of exotic media may simply become an expensive way of transmitting relatively trivial facts. Evaluation of the educational effectiveness of various media as ways of presenting materials will give answers to questions as to when certain media will be helpful and when their cost is justified.

Integration

The history of biological education has been one of a constant coalescing of normally separate disciplines. Botany and zoology, in many instances, have been combined under the single rubric of biology. Biology deals with an entire field and provides a synthesis not otherwise possible for the student who sees only segments of the discipline in courses of anatomy, physiology, systematics, etc. But just as there has been a tendency to coalesce the individual identities of the biological sciences into one, so also tendencies are found to develop courses in science that include not only biology, but chemistry, physics, and the earth sciences as well. The next step seems to be to extend science into the realm of the social sciences, and to integrate the natural sciences and social sciences in a common matrix dealing with specific problems (24). Ultimately, to this matrix will be added humanities, and students will receive a still more integrated view of the world through combinations of what have, in the past, been separate and discrete disciplines. These integrative steps need constant evaluation to ensure they are contributory rather than divisive.

Minorities and women

A curriculum needs to provide positive reinforcement to all segments of the population. This

means largely removing stereotypes that show women and minorities in specific activities that tend to categorize their position in society (22). In India, curricular materials are now appearing in the various native languages of different sections of the country; bilingual education is emerging in areas of Canada, where the languages are English and French, and in the United States, where greater emphasis is being placed on adapting to the needs of Spanish-speaking students. Curricular materials should reflect the needs of all cultural and ethnic minorities. The role of women is different in many countries, depending on local customs and traditions; for the most part the tendency is to give women a greater share of the decision-making roles in society. Curricular materials are also now reflecting the complete integration of male and female roles in the various aspects of a discipline. Evaluation must ensure that bias against ethnic and cultural minorities, and bias on the basis of sex, is eliminated from curricula.

Accountability

Because education is a concern of the state and the citizenry of the state, it is more and more being asked to account for its actions, its progress, and its product. Education for education's sake is not held in as high esteem as it used to be. Questions of Why? What? Where? When? and How? are being asked, and the curriculum segments of our educational systems are expected to justify their content and to account for progress. It is to this end that evaluation has changed from the evaluation of individual students for purposes of assigning grades, to the evaluation of a school, a curriculum, a teacher, a programme, or a set of values. All segments of the educational enterprise will be evaluated against a series of aims or objectives, and the effectiveness of education will be judged by its ability to show how well it has achieved the goals and objectives proposed.

DISSEMINATION

INTRODUCTION

Frequently curriculum developers envision their role in education as simply that of creating new curricula, and view the school's role as one of acceptance. Schools, however, more frequently interpret their own role differently. They see evaluation as their first responsibility, and they regard the curriculum developer as an interested outsider (27). Evaluation has been so far discussed as an intrinsic part of curriculum development. Curricula are ultimately evaluated a second time; that is, through use in the schools. It is this second evaluation that involves the realm of dissemination, where curriculum developers must not only inform educators of the existence of a new curriculum and its potential, but must supply the curriculum product and in some cases, even create the demand for it. To ensure maximal effectiveness, the developmental function should be divorced from those who adapt, mandate or conduct summative evaluation upon the new curriculum.

DISSEMINATION CRITERIA

Curricula that are ultimately chosen for use are those that communicate in their dissemination activities the greatest combination of high promise (product effectiveness) and low risk (accessibility).

Product effectiveness criteria

The high promise features that encourage the adoption and use of new curricula include the following.

Obvious relationship to education needs. That curriculum shows the greatest promise that satisfied the majority of a country's educational objectives, whether those be the training of professionals or paraprofessionals, the institution of an enquiry of problem-solving approach, an emphasis on environmental education, the coverage of basic principles of good health and other applied aspects of biology. The curriculum that fills these needs alleviates certain problems and thereby passes one of the primary steps for acceptance.

High apparent validity. This criterion implies a guarantee of results and usually contains accountability procedures against which curriculum claims can be measured. In short, it demonstrates that the curriculum does what its creators said it could do.

Abundance of new, easy-to-use teaching and learning ideas. Teachers appreciate new ideas and teaching suggestions, but not if they are unduly demanding or excessively complex. The curriculum most likely to be disseminated is one that offers the teacher new techniques and concepts that are both easily assimilated and applied.

High interest value for both teacher and student. Teachers gauge their success by student interest in what is being taught, but unless material is initially interesting to teachers, it may never be presented to the students. Dissemination efforts should be focused on capturing the interest of both teacher and students.

Attractive packaging. Both students and teachers are most favourably disposed to materials that are well printed, well illustrated, colourful, and tastefully produced. Given the choice between smudged mineographed copies on low-quality paper and clean type on glossy paper, illustrated and bound in an attractive cover, the average student or teacher clearly and quickly demonstrates the focus on package attractiveness. This criterion is cost dependent and certainly ranks as the lowest priority item in the sequence of product effectiveness criteria if the first four criteria can be met.

Accessibility criteria

The corollary to high promise, which implies mechanisms that will best help the students learn, is low risk; that is, a curriculum readily accessible to the teacher. The low risk accessibility criteria are as follows.

Materials that pose the least threat to a teacher's training and capabilities. A curriculum that is likely to have the greatest success is one that is least threatening to the teacher. It is one that neither demands a completely new type of teacher nor requires teaching strategies and techniques beyond the capacities of the present teacher. Almost all new curricula include materials that will be new to the teacher, and many demand teaching styles at variance with those previously used. This ever-present threat to the teacher is greatly reduced when dissemination activities include an attractive training package that enables the teacher to obtain easily the confidence and competence needed to handle the programme. This package can be directed to the individual teacher in the form of a detailed teacher's manual to accompany the curriculum, or it may involve periodic in-service training sessions. Whatever form it may take, it must make adoption of the new programme easier for the teacher. Any curriculum is in difficulty which threatens rather than facilitates teacher acceptance through its dissemination plan.

Fewest outside values imposed on teaching. A new curriculum that has a relatively high degree of familiarity and that makes no severe challenges to values that are an intrinsic part of the teaching scheme is the easiest to disseminate. Obviously all new materials impose some new values, but how well these can be introduced effectively is directly related to how little disruption they will cause. Sometimes this consideration forces curriculum developers to prepare stepwise

materials that move toward desired goals in small increments. Attempted dissemination of giant steps forward frequently fails because the target population cannot effectively assimilate the new values such a step requires.

Least revision of classroom strategies. All new curricula demand some changes in classroom strategies. The enquiry method involves more dialogue between teacher-student and student-student than many teachers have been used to. Most teachers who are amenable to some use of the enquiry method would reject a programme that demanded its 100 per cent daily application. Dissemination activities must tie the new curriculum to existing teaching styles before introducing more varied approaches.

Least requirement for before-class preparation. Complex and demanding curricula that require teachers to spend hours outside of class preparing for a single presentation are likely to become so demanding as to be rejected. The numbers of classes, the numbers of students, and the number of outside tasks already handled by teachers is considered by many to be excessive. Additional burdens are not welcome, and new curricula are most likely to be adopted when they require only minimal additions to an already heavy teaching schedule. Dissemination efforts need to emphasize the ease of preparation requirements and to demonstrate that they can be handled without excessive demands on the teacher.

Least overall stress in teaching style. Here again, it is impossible to introduce a new curriculum without developing at least some initial stress in teaching style. Teachers who have been used to communicating exclusively through the lecture method, find the introduction of laboratories – initially, at least – demanding and threatening. The use of multimedia or marked change in an already familiar syllabus or examination can make a teacher uneasy, but the less stressful the curriculum appears to the teacher, the greater the possibility of its effective implementation. It is the role of dissemination to reduce the stress potential inherent in new classroom materials.

DISSEMINATION TARGETS

It is paradoxical that curriculum developments should be targeted toward students when students are hardly in a position to determine curriculum adoption. Only indirectly, by their demonstrations of apathy or enthusiasm, achievement or disenchantment, can students influence the adoption or rejection of a particular course of study. Governmental agencies, administrators and teachers adopt curricula, and each views the adoption from slightly different vantage points.

Governmental agencies

Educators in countries without strong central ministries frequently envy countries like France and New Zealand, whose ministries both initiate and control curriculum development. In those countries dissemination can be directed to occur. Conversely, educators in countries with dominant central control of the educational process may envy those countries with decentralized educational systems, such as the United States, the Federal Republic of Germany, or the United Kingdom. Such decentralization favours a wide variety of experimental approaches and provides greater autonomy at local levels. The effectiveness of a national, centrally determined curriculum seems correlated with the homogeneity of a country's population and culture, as well as with small-sized, compact populations (23). Factors that influence governmental decisions include a tradition of centralized decision making, economic limitations, and the influence of social interest in the school curriculum, particularly on the part of political parties, organized religion, or societal tradition.

Administrators

In this outline, administrators are defined as regional or local, rather than national. Even in strong, centrally controlled systems, however, directives pass through the hands of geographically dispersed administrators whose abilities to disseminate the curriculum decided upon at higher levels will vary with local conditions. These administrators may be concerned with the cost effectiveness of the programme under consideration, funds for its maintenance after adoption, the availability of its materials, and its suitability for the local situation. In addition to the central government influence, regional administrators are affected by pressures from various regional groups – parents, labour unions, teachers – plus microcosms of all the pressures affecting a central ministry. With a strong central authority, regional administrators at least have external reference points for their actions.

In those countries that lack such central control, it is the regional administrator who may be responsible for the curriculum decisions of his area, with no recourse to higher authority. Dissemination efforts must be directed toward answering the administrator's questions about why a specific curriculum should be introduced into the system under his control. In order to answer the questions that will be directed to him by parents, teachers, and others, the administrator seeks exact information. Any dissemination effort that cannot provide him with sufficiently precise answers risks not being considered for adoption.

Teachers

The high-promise, low-risk attributes of dissemination listed earlier are of concern primarily to teachers. The effectiveness of a dissemination activity is measured by how well the original philosophy and design of the programme are applied in practice. For this, each teacher is independently responsible. Teachers thus play a critical role in innovation, not simply as implementors, but as innovators themselves. They assume creatively adaptive roles in modifying the innovations of others to suit the particular circumstances of their schools. While this activity may be of paramount importance in formative evaluation, only a relatively small number of teachers are involved in such evaluations. Larger numbers of teachers can play a significant role in summative evaluation, based on their experiences with implementing activities.

TEACHER EDUCATION AND DISSEMINATION

Teacher education agencies play an important part in effective dissemination and implementation. They are involved not only in in-service training activities, which may be conducted by ministries, colleges of education, individual schools, labour unions, or curriculum development projects themselves, among others, but also in pre-service teacher education (see the chapter on 'Training and retraining of teachers'). Unfortunately, except in those instances where a strong national authority not only dictates curriculum development but also controls teacher education, pre-service teacher education almost uniformly exists in isolation from the mainstream of curriculum innovation. The lag in pre-service education of teachers is frequently obscured because most curriculum innovations do not deviate significantly from established practices covered by the faculties of teacher education institutions. When the innovations deviate markedly from prior practice, therefore, recently graduated students of such institutions must frequently proceed immediately to in-service training sessions to prepare themselves for implementing curriculum innovations.

DISSEMINATION DESIGN

It is obvious that every curriculum development project must design a plan for dissemination. A model for curriculum dissemination leading to implementation is shown in figure 3. It is further obvious that the dissemination plan will be conditioned by governmental policies and laws and will use the body of experience accumulated through contact with national and local agencies during the experimental use period in pilot schools. The magnitude of the dissemination project depends on the type of curriculum innovation. Obviously one teacher working on new materials for her own classes has a relatively simple dissemination plan, but the problems are compounded as more teachers, more schools, and more areas become involved. Some curriculum innovations have extended far beyond national boundaries to become truly international in scope, and these larger projects present problems of language, culture, facilities, budget, and so on, that greatly affect the dissemination plan. Thus, curriculum design will depend on what is to be disseminated – a complete course or simply course concepts, the entire package or only that part which differs from what is currently being done.

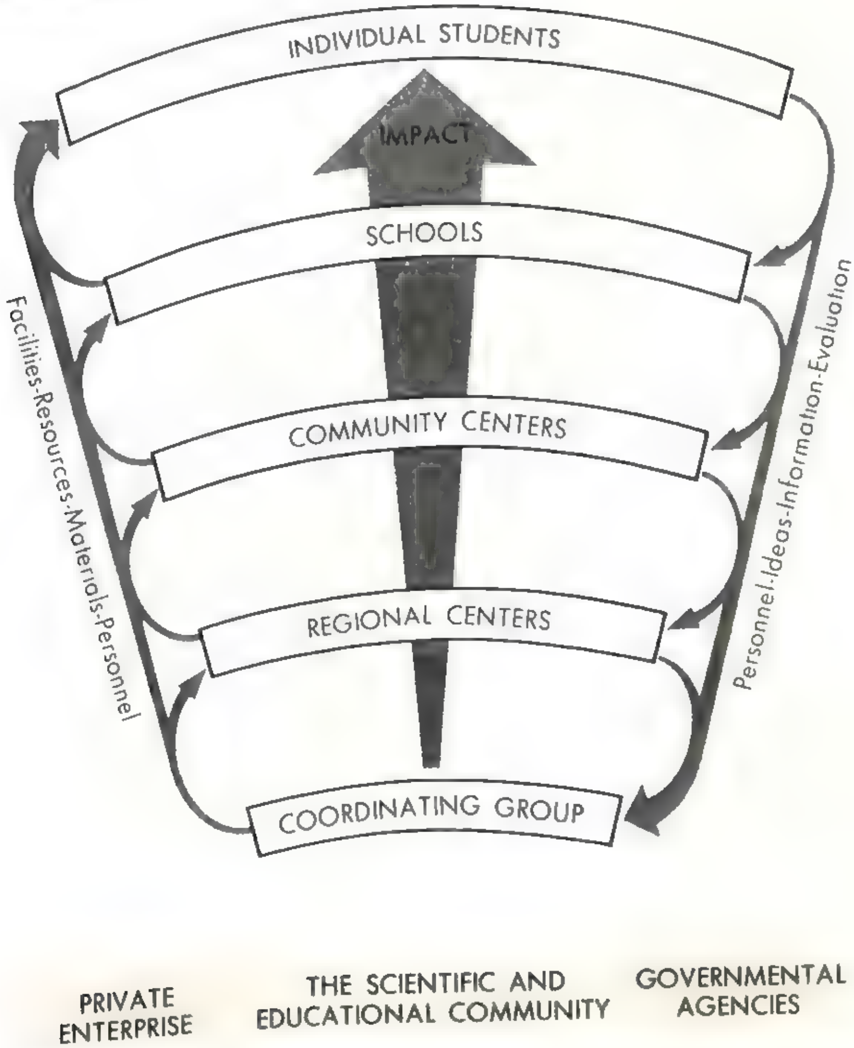

Fig. 3. A model for curriculum implementation. The vertical structure of organizational units is interconnected through feedback communications channels to provide a close working relationship between curriculum developers, school administrators, teachers and parents. The mechanisms required to bring about this type of co-operative effort do not presently exist in most educational structures, but the idealism reflected in the model is a dissemination goal for which to strive.

Early communication with the educational community

This includes announcements in educational journals that indicate the establishment of a new curriculum development project, the nature of its activities, the staff, its headquarters, and the service mission to teachers and schools. Interested inquiries should be invited, and perhaps from these, individuals can be selected for participation in various phases of the development or dissemination effort. These announcements are usually in the form of articles submitted to various educational publications, although it would be neither unethical nor improper to explore a paid educational advertisement.

Disseminate a strong image. It is important to achieve in these first messages at least a neutral but preferably a favourable response (18). Positive image building from the beginning includes not only presenting a favourable image of the programme itself, but also projecting a positive image of staff members to the educational community. If the initial announcement evokes unfavourable attitudes, the project is in difficulty from its inception. It should be emphasized, however that each public announcement made by the project constitutes a first message for someone.

Mailing list. Development of a mailing list should include the names and addresses of those who have written for information, as well as those listed in educational directories or known to the project staff. This list should concentrate on those who are concerned with the target population and the curriculum area of the project.

Brochures and newsletters. It is helpful if an informational brochure can be developed as a simple mechanism for answering the majority of questions concerning the project. A newsletter is an effective communication device, provided sufficient creative talent is available to ensure maintaining a regular schedule of publication, and so long as funding for such an activity can be obtained.

Personal contact. Visitor service at the project headquarters can provide firsthand information to those interested. Participation in educational meetings and conventions, not only by means of papers presented, but also by exhibiting the project's material, will materially aid in keeping the target audience informed.

Workshops

The project should keep in mind the opportunities to conduct workshops. These can be arranged with interested teachers at a given meeting or can be specially designed for regions where interested teachers can be easily congregated. Invitational workshops at the project's headquarters can be considered, as well as workshops or in-service courses at colleges and universities. Summer institutes and academic year institutes where such training facilities are available should also be explored. Ultimately, the workshop function should be transferred to the agent marketing the completed curriculum to provide for maintenance of the communication channel. In some areas, as in Japan, science education centres are available on a formal basis for workshop activities (29). In some countries, such as Kenya, a publication foundation has been set up by the ministry to ensure availability of materials for teacher and student use.

Production of model materials

A modest overprinting or overproduction of the prototype product and training materials should be purposely authorized. Those materials not needed in pilot classes can be used in a variety of workshops or other training activities, and can be paid for by those conducting or attending.

DISSEMINATION STRATEGY

A dissemination strategy must be evolved. It should respect the teachers' professional backgrounds and been in mind how innovations will affect their careers, and take into consideration what financial implications, if any, are involved. The strategy should also take advantage of the teachers' training and experience, and should relate to current practice. It should capitalize on the rejection or growing frustration with curricula then in use. It should consider teachers' opinions of the capability of their students and the classroom constraints under which they work. It should take into account the level of trust and respect between teachers, administrators, and innovators. Most importantly, it must lead to internalization of an innovation; that is, there must be complete comprehension of the innovation in a personal sense, and not as something that requires constant external application from outsiders. The strategy must involve teachers in a contributory fashion and cannot consider them merely as passive receptacles for the ideas of others. If teachers are to receive both personal and professional satisfaction, somehow they must provide an element of their own creation in the programme.

Administrative and material support

It is essential to have both administrative and material support for innovation, for without it teachers will feel abandoned and dissemination programme will fall into disrepair.

Examinations

As mentioned earlier under evaluation, the examination system must be flexible enough to accept the dissemination of new materials and to incorporate them into its framework. Syllabuses, examination papers, and assessments must include the new ideas that have been adopted. One cannot ignore the fact that examinations in many countries are themselves significant dissemination mechanisms.

Dissemination vs. publicity

Whatever the scale of a curriculum development project, effective dissemination is a major responsibility. Whatever means are available for this important task should be fully utilized if the development effort is to be accepted by the target population. A fine line must be drawn in dissemination activities between blatant publicity, which will be regarded as self-serving, and the provision of information for intelligent decision-making, which is a valuable contribution to the educational process. Dissemination activities should be designed to provide information while maintaining academic integrity, for without such information, informed decisions cannot be made. If no basis for decision-making has been provided, curriculum development projects are likely to fail, regardless of their high aims and potentially valuable contributions.

SUMMARY AND RECOMMENDATIONS

Evaluation must be an intrinsic part of the design of every new curriculum. It begins with a needs assessment and establishes objectives designed to fill those needs. It precedes curriculum development, is an intrinsic part of it, and may continue for years after the curriculum has been introduced in the schools. Likewise, dissemination planning with a view to implementation of the programme as envisioned by its designers must accompany every stage of the curriculum develop-

ment process. Intelligent use of dissemination will ultimately lead to the acceptance and implementation of the finished product. Both evaluation and dissemination schemes are dependent upon the curriculum developers for their success, but the curriculum developer, in turn, is responsive to a wide variety of publics before his contribution can find its way into the hands of the intended student population. The skill with which evaluation and dissemination techniques are used often spells the difference between the success or failure of a curriculum innovation.

Recommendations

1. Formative evaluation of a programme could be done by the curriculum developer, but the summative evaluation should be done by a technical and independent group.
2. Regional centres dealing with biology education should be strengthened and their role in dissemination should be supported. (publishing and distributing technical reports and practical papers dealing with case studies of curriculum evaluation). Stronger links should be established among various national and regional centres to facilitate exchange of information on curriculum development and evaluation.
3. The (TUBS-Unesco) should be strengthened and supported in order to reflect the various trends and experiences of curriculum evaluation and dissemination.
4. The publication of a handbook for curriculum development and evaluation appears to be very useful; it would consist of two parts:
   - comparative survey of various practices of curriculum evaluation;
   - practical models of curriculum evaluation of various levels of complexity and sophistication to fit the various needs of the countries in accordance with their resources.

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The understanding of the learning process and the effectiveness of teaching methods in the classroom, laboratory and field

INTRODUCTION AND HISTORICAL BACKGROUND

With the emergence of the public secondary school in the latter half of the nineteenth century and the expansion of college studies to include more science, the teaching of biology begun to acquire a prominant role in school curricula. Early studies drew heavily on distinguished scholars in botany, zoology and physiology, the latter commonly associated with studies in medicine. Textbooks were largely catalogues of information, usually organized according to taxonomic systems or, in the case of physiology, according to systems of the body. Instructional methods stressed memorization of factual details with a minimum of emphasis on important biological concepts which serve to organize the known facts and to provide an understanding of the way in which living systems function.

The period from 1850 through the first quarter of the twentieth century was characterized not only by an expansion of factual knowledge about living things but also by the development of explanatory models or broad, general concepts that explained some of the observed regularity in living systems. The concepts of evolution, genetics, cell and germ origin or disease are a few of the major explanatory concepts advanced in this period. At a later stage, we will show how the

concepts embodied in a discipline play an important role in governing methods for obtaining new knowledge in the discipline and how they influence the design of instruction. It will be argued that concepts [1] play a central role in rational human behaviour and that concept learning should be the focus of attention in biology teaching. It follows that our psychological model for learning must be one that places emphasis on the nature of concepts and the role of concepts in learning. It will be seen that there is only one viable theory of cognitive learning broad enough to meet our demands—the learning theory of David P. Ausubel (1968).

As new knowledge in the sciences continued to accumulate at an accelerating, rate, it became increasingly evident that new approaches to science instruction were needed. The traditional 'survey' of knowledge, phylum by phylum in the biological sciences, was seen to be increasingly deficient. In the United States, textbook authorship at the secondary level shifted from scholars in universities to teachers and headmasters in public and private schools. This shift from those concerned with research to teachers in schools led in part to the later obsolescence of knowledge of secondary programmes that provided one of the incentives for new curriculum programmes supported in the United States by the National Science Foundation and requiring substantial contributions from distinguished research scholars (cf. Hurd, 1961). A somewhat parallel pattern occurred in England when new programmes were developed with the support of the Nuffield Foundation. At the college level, numerous efforts were made to devise new curricula and new instructional approaches. Some of these 'innovations' have been described in two volumes by McGrath (1948) and Haun (1960), both volumes entitled, *Science in general education.* At the elementary school level, science was being increasingly recognized as a valid subject of study, and federally sponsored programmes for elementary schools were included in the active curriculum development years of the 1960's. (See the chapter on 'The development and design of new course in secondary biological education').

Most of the curriculum development projects of the 1960's focused on the updating of content and on 'methods of scientific inquiry,' the latter patterned along the lines of Popper's *Logic of scientific discovery* (1959). The American Association for the Advancement of Science sponsored an elementary school programme, Science: a process approach, designed to emphasize 'scientific processes' according to a hierarchical structure advocated by Gagne (1965). None of the major United States or United Kingdom curriculum projects placed a central focus on the nature and role of concepts in scientific discovery, nor on the role of concepts for learning and understanding science (cf. Novak, 1969).

Without neglecting the contribution of genetical psychologists (Piaget, Bruner), of others such as Freinet, Montessori, and the work by teams from the Nuffield Projects, Kiel IPN and Paris INRDP, which emphasize the building up of science by the pupils, this chapter will insist on the importance of the conceptual framework of the discipline to be taught and of a systematic analysis of instructional alternatives selected to maximize concept learning by the students. It will be shown how new insights from learning theory can guide and support the design of instruction to facilitate learning for students with a wide range of learning aptitudes.

THE CHANGING EPISTEMOLOGICAL FOUNDATION OF SCIENCE

There has been much progress in the sciences during the past century, particularly in the biological sciences where our knowledge of living systems has changed enormously. What has not been generally recognized is that the nature of science as an active search for knowledge has also changed.

The history of modern science goes back to the writings of Copernicus in the early 1500's

1 There are many and varied definitions of concepts. According to Novak, it is useful to define concepts, as 'a description of a *regularity* among facts or other concepts'. Facts are defined as records of *events*, and events are things that we observe happening or make happen. Thus, an *experiment* produces *events* that are *recorded* as observed *facts* whose *regularity* we try to explain with relevant *concepts*. Sometimes we need to invent new concepts to explain the regularities we observe.

and Galileo in the early 1600's. Both of these men were careful observers of nature, as were Aristotle and others, but unlike their predecessors of antiquity, they sought explanations of phenomena not through properties inherent in the objects themselves, but rather through relationships between objects frequently expresses in mathematical terms. Thus, Galileo found that large stones fall at just the same rate as small stones even though the latter weigh less, and so on. The early seventeenth century was a period when interest in observing nature was burgeoning in Europe, a time when many educated gentlemen saw science as a suitable intellectual hobby. Francis Bacon joined in the sport of performing experiments and observing nature; however, his most important contribution was his extensive descriptions of methods for studying nature. His early writings and especially Novum Organum, written in 1620, spelt out the dogma of scientific practice:

> 'The subtilty of nature is far beyond that of senses or of the understanding; so that the specious meditations, speculations and theories of mankind are but a kind of insanity, only there is no one to stand by and observe it'. (1620, 1950 p. 107).

Bacon and others drummed home the point that science would advance best if we observed nature unfettered with preconceptions of what should be seen or how nature should behave. Given the speculative, philosophical character of much early and medieval science, the emphasis placed on careful observation and on neglect of irrelevant preconceptions was a necessary stage in the evolution of science as an enterprise for gaining new knowledge. Bacon's influence continued throughout the seventeenth, eighteenth and nineteenth centuries. For example, Darwin wrote:

> . . . 'By collecting all facts which bore in any way on the variation of animals and plants under domestication and nature, some light might be thrown on the whole subject. My first notebook was opened in July 1837. I worked on true Baconian principles; and without any theory, collected facts on a wholesale scale' . . . (p. 67, 68).

We know, of course, that Darwin went beyond a description of the facts he observed during his voyage in the Beagle; he later formulated and expressed in detail his theory of evolution in *The origin of species* (Darwin, 1859). And we also had the 'laws' of Kepler in astronomy, Newton in physics, Lavoisier in chemistry and Pasteur in microbiology. All these 'speculative' conceptualizations notwithstanding, Karl Pearson still wrote in 1900:

> '*The unity of all science consists in its method, not in its material.* The man who classifies facts of any kind whatever, who sees their mutual relation and describes their sequences is applying the scientific method and is a man of science. (p. 12) (italics in original).
> . . . As I interpret that theory (Darwin's evolution) it is truly scientific, for the very reason that it does not attempt to explain anything. It takes facts of life as we perceive them, and attempts to describe them in a brief formula' . . . (p. 356).

After Pearson we had Einstein's work; Mendel's genetics was rediscovered and modern genetics emerged; quantum theory was developed. These and many more conceptual frameworks were devised to facilitate the observation of nature and to guide the design of instruments and experiments. But we still find leading philosophers of science propounding the view that experiments and observation are the core of scientific enterprise and the crucial issue is the logical relations between experimental facts and hypotheses. Karl Popper (1934, 1959) asserted that, 'the results of an inquiry into the rules of science—that is, of scientific discovery—may be entitled, 'The logic of scientific discovery'." (p. 53). Since the dogma developed by Bacon was established, that science was based on observation and experiment and that the methods used to perform these impartial, impersonal observations were the essence of science, we have had three hundred years of acceptance of this dogma.

In the 1950's, however, there began to emerge a new view of science, led by people who were careful students of the history of science. They found in the life and letters of the practicing scientists a central role of speculative conceptualizations; important and crucial choices of experimental procedures were determined by what Polanyi (1957) called passion, and not logic; and a growing recognition that in science, as in other human enterprises, the conceptual heritage

largely governed what a scientist saw and how he thought. Conant expressed this in *On understanding science* (1947) and his protege, Thomas Kuhn, developed the thesis that the conceptualizations or paradigms that guide the scientist's work determine the methods he will use and what he will see in his observations. Kuhn's (1962), *The structure of scientific revolutions*, while criticized for ambiguity in definition of paradigms and for emphasis on the 'revolutionary' transition from old to new paradigms, nevertheless helped to deal a death blow to the myth that science was a 'logic of discovery' or a nonsubjective data gathering enterprise.

More recently, Stephen Toulmin (1972) has shown that Popper and others are caught in their own logical traps in that their search for scientific 'truth' through logical methods leads to an 'infinite regress' whereby something must be assumed to be true, and whereby, in checking back on our assumptions, we eventually find some *a priori* 'truth' that must be taken on trust. Rather than pursue a 'logic of discovery', Toulmin argues that we should accept that *rational* thinking and logical thinking are not identical:

> 'A man demonstrates his rationality, not by a commitment to fixed ideas, stereotyped procedures, or immutable concepts, but by the manner in which, and the occasions on which, he changes those ideas, procedures and concepts'.

To Toulmin, *rational* behaviour is the key to advancing knowledge and rational behaviour is described by the ways in which concepts are used to observe and to interpret phenomena. Moreover, there are no absolute' concepts that remain true and viable for all time, so that what is rational behaviour in one decade or century may be irrational behaviour in another period. For example, when the "creationists" concept was dominant in society, it was irrational to suggest that living things as we see them evolved gradually from ancestral forms for this conflicted not only with literal interpretation of the Bible, but also with the 'fact' that too many changes were needed in the brief span of time from 4004 B.C. when the earth was allegedly formed. As various lines of evidence began to suggest that the world was much older—billions of years old—the creationist concept lost a major intellectual prop, and now it is irrational to assume that catastrophic rather than evolutionary models best explain the world we observe. Toulmin argues that human understanding is based on the concepts that man holds at any point in history and that the concepts are evolving:

> 'Concepts, like individuals, have their histories, and are just as incapable of withstanding the ravages of time as are individuals'.

A new period in the history of science is beginning, when increasingly the historians and philosophers of science will be discussing more accurately what it is that the scientists have done or are doing. There may be fewer shock waves when future Nobel Prize winners admit to the conceptual game they played, as did James Watson in his book, *The double helix* (1968). So different are the new perspectives of the nature and history of science that one writer has asked, 'Should the history of science be rated X?' (Brush, 1974). Elementary science textbooks and popular mythology have held such a distorted view of science and scientists that Brush wonders if the realistic, human character of science may appear obscene to a public raised on the cold, objective, mythological image of science.

To sum up, if science is recognized as evolving populations of concepts which guide both our methods of inquiry and our imterpretations of our findings, should not science instruction also focus on concept learning? According to Novak, the answer is yes. Therefore, one has to search for a theory of learning that can give guidance in the process of planning curriculum and instruction to effect learning in biology where concept learning is at the heart of our effort. The reasons for selecting Ausubel's theory over the work of Gagne, Piaget or Skinner are presented elsewhere (Novak, 1975).

THE COGNITIVE LEARNING THEORY OF DAVID AUSUBEL

To begin with, it is important to distinguish between three types of learning: cognitive learning,

affective learning and psychomotor learning. Cognitive processes are those by which we acquire and use knowledge; They are what most people mean when they speak of learning, especially school learning. Cognitive learning results in organized storage of information in the learner's brain and this organized complex is referred to as cognitive structure. Affective experience results from signals that arise within the individual, and these are identified as pleasure or pain, satisfaction or dissatisfaction, contentment or anxiety. Some affective experience always accompanies cognitive experience, and hence affective learning is concomitant with cognitive learning; but the important thing to recognize is that we as educators can only arrange for the cognitive experience, and therefore this should properly be our focus of attention. Psychomotor learning involves training of muscular responses through practice, but some cognitive learning is usually an important element in the acquisition of psychomotor skills, e.g., piano playing or ballet dancing.

Ausubel's theory deals primarily with cognitive learning. This is not because he has little interest or expertise in the area of human emotions; he is in fact a practicing psychiatrist. According to Novak, this cognitive learning theory is the most useful and comprehensive learning theory available. The discussions in this chapter focus on cognitive learning not because affective experience is unimportant, but because there is much immediate promise for improvement of biology teaching through the application of Ausubel's cognitive learning theory.

Meaningful learning

The most important concept in Ausubel's theory is what he describes as *meaningful learning.* Meaningful learning occurs when new information is linked to existing *relevant concepts* in the learner's cognitive structure. For example, a student who observes that a phasmid is not a stick but an insect, with eyes, legs and other things that insects have, has not only learned to recognize this species but can relate his new learning to a large array of information he may possess regarding insects. The example also serves to illustrate another important principle—the *degree* of meaningfulness for a new learning experience will vary from student to student depending on the adequacy of his relevant concepts. A child who knows little about insects will not have the same meaningful learning experience in an encounter with a new insect as will a child who has made insect study his hobby.

In contrast to meaningful learning, it is also possible to learn new information with little or no linkage to existing elements in cognitive structure. This is generally regarded as *rote-learning.* However, the meaningful-rote distinction is not a dichotomy but rather a continuum. Even learning telephone numbers has some degree of meaningfulness, for we know that in the United States and Canada all numbers are seven-digit, and that the first three numbers in any city commonly represent a given district; when one knows this, only the last four digits need to be learned by rote.

Subsumption and obliterative subsumption

In the course of meaningful learning, new information is linked with existing concepts in cognitive structure. However, this is a dynamic process and both the new information and the existing concept in cognitive structure are somewhat altered. To emphasize this point, Ausubel calls the existing, relevant concept in cognitive structure the *subsuming concept* or subsumer. The linkage of new information with a relevant subsumer in the course of meaningful learning is the process of *subsumption.* Ausubel symbolizes the process in this way:

Subsumption:	A	+	a	–	A'a'
	existing concept in cognitive structure		new relevant information to be learned		modified concept in cognitive structure

This process is shown graphically in fig. 1.

For a period of time, the new information learned ('a') can be recalled almost in its original form, but in time it will no longer be dissociable from the subsuming concept. In this case *obliterative subsumption* has occurred. Obliterative subsumption is different from forgetting as it occurs in rote learning. After obliterative subsumption, the residual concept remains and much of the growth that occurred during subsumption is retained so that this concept is strengthened and more capable of facilitating *new* meaningful learning in the future. In contrast, after forgetting has occurred following rote learning, new similar learning is actually retarded by a process described as *interference*. We have probably all had the experience of having difficulty in learning a new telephone number that is similar to an old number which we can no longer reliably recall. In contrast, learning the characteristics of a new plant or animal that belongs to a family we know well may take place with one or two reviews of the information.

Superordinate learning

In the course of meaningful learning, new facts may be linked to concepts in cognitive structure thus strengthening and broadening those concepts. It is also possible for new learning to result in new associations between concepts. For example, as a child's concepts of dogs, cats, lions,

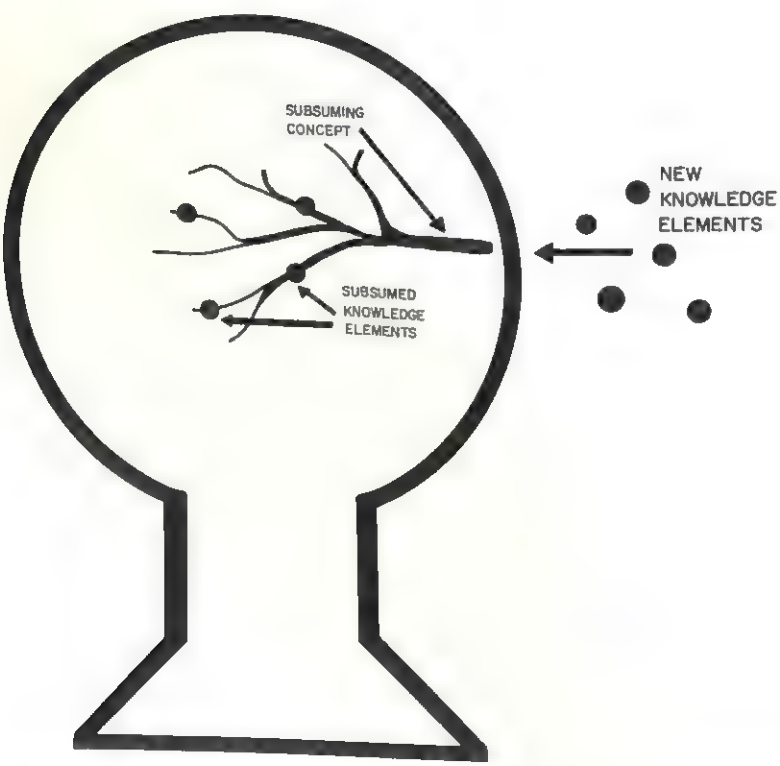

Fig. 1. In meaningful learning, new knowledge is subsumed by existing concepts in cognitive structure.

etc. develop, he may learn that all of these are subordinate groupings of a more general class—mammals. As the concept of mammal is developed, the previously-learned concepts of dog, cat, etc., take on a subordinate relationship and the concept of mammal represents *superordinate* concept learning.

Progressive differentiation and integrative reconciliation

As the subsumption process proceeds, existing concepts become more elaborated or more differentiated. This process may extend over days, weeks or years, and it is important in the design of instruction to make deliberate efforts to encourage students to associate new information with previously learned, relevant concepts, thus *progressively differentiating* these concepts.

In the course of learning and concept differentiation, conflicting meanings may arise. For example, as a student studies botany, he may find confusion in recognizing pea- or bean-pods as fruits even though they represent the mature, ripened ovary of a flower. His early home training in nutrition may have included peas and beans along with carrots and beets in the category of vegetables. Thus it is important to distinguish between plant structures according to food groupings from classifications according to botanical concepts. The process by which conflicting meanings between concepts are clarified is known as *integrative reconciliation.* It is a necessary process and should be guided by the instruction. Usually both superordinate learning and progressive differentiation occur simultaneously as concepts are clarified and integrative reconciliation is achieved.

Advance organizer; cognitive bridge

One of the most misunderstood elements of Ausubel's theory is his concept of *advance organizer.* When the concept was first introduced in 1960, Ausubel showed evidence that a properly designed instructional sequence (the advance organizer) introduced prior to new information would facilitate learning of the latter. The characteristic that Ausubel emphasized for the advance organizer was that it should be more general and more abstract than the information to follow and that it should serve to facilitate 'meaningful' learning of the new material. Much of the research that has been done to test Ausubel's theory has centred on this single concept, but unfortunately Ausubel's original intention is seldom achieved with the type of advance organizers that have been used.

The crucial element of an advance organizer is that it should serve *to link* the new information to be learned with existing concepts in cognitive structure. Rarely have researchers taken into account the nature of the learner's cognitive structure *and* the potential meaningfulness of the new material to be learned. It is unlikely that an advance organizer can be written for learning nonsense words or to link new information that cannot be related to any of the learner's concepts.[1] For this reason the "linking" or "bridging" function of advance organizers should be emphasized and reference will hereafter be made to *cognitive bridges* rather than to advance organizers. Cognitive bridges are short segments of learning material that provide the student with guidance as to which concepts in his cognitive structure might best be employed to learn meaningfully. They also help to signal what will be the key concepts in the new material and how these may bear a subordinate or superordinate relationship to concepts the learner already has.

1. Although Ausubel suggested that an "expository" advance organizer could be used to facilitate learning of completely unfamiliar (i.e., unrelatable to existing cognitive structure) material, the empirical evidence indicates that this view should be rejected.

An example of a cognitive bridge commonly used in biology is the concept of structure-function complementarity. When attention is called to this concept prior to instruction on the nature of xylem elements, or bone or cartilage or other structures, the probability of meaningful learning resulting in progressive differentiation and integrative reconciliation of concepts is enhanced.

Problem solving, discovery, inquiry

According to Ausubel's theory, the crucial test for meaningful learning is the ability to solve *relevant* novel problems. If a student has learned meaningfully some aspect of gene structure or function, he should be able to solve novel problems of genetics relevant to that learning. Problem-solving ability then *derives* from cognitive structure differentiation and is *concept specific.* To be sure, some broad concepts bear upon a wide array of problems, but usually more specific, subordinate concepts are also needed to solve a given problem. Thus, from an Ausbelian view, there is no general strategy or logic of discovery, except the general strategy of meaningful learning. And meaningful learning is primarily a function of concept development and integrative reconciliation. Most curriculum development efforts of the past two decades have focused on 'inquiry' or 'discovery' methods as an alternative to the rote learning that has been so common in schools. Consequently, they have 'thrown the baby out with the bathwater'. They have failed to recognize that the direct facilitation of concept learning is not the same as teaching for rote learning and that it is the only way substantially to enhance problem-solving or inquiry capabilities.

It should be noted that the act of problem-solving is actually a process of meaningful learning. As an individual gathers information from the problem situation, he meaningfully internalizes new elements, thus differentiating some concepts further and forming new associations among subordinate and/or superordinate concepts. Problem-solving is in reality no more than a special kind of meaningful learning.

Creative ability

There are many different descriptions of creative ability, but they agree in one respect—all involve some form of novel product or solution. For the creative architect, the product is a design; for the musician, it may be a ballad or symphony; and for the biologist, it may be a clever experiment or a new model for gene structure. In every case, the creative person is drawing on a store of knowledge and synthesizing a new 'solution'. The creative process is essentially an advanced form of superordinate concept differentiation and integrative reconciliation. It is dependent upon the presence of many low-order concepts and facts (our equivalent of the capability usually measured by I.Q. and standardized achievement tests), but *crucially* dependent upon the individual's *capacity for, and emotional proclivity to, structure high-order, superordinate concepts.*

Unfortunately, much of school learning and evaluation stresses fact memorization or learning of low-order, specific concepts. The result is that the use of creative potential is discouraged and schooling as now practiced has frequently been cited as a deterrent to creative production, especially in the humanities. However, the power of high-order concepts for facilitation of meaningful learning and acquisition of new knowledge is so great that "high creatives" do as well or better than their "high I.Q." classmates even by the criteria used in schools! (cf. Getzels and Jackson, 1962 and Torrance, 1962). The creative output of scientists on the job bears also no correlation with college grades (Harmon, 1963) and ability to use high-order concepts in solving physics problems is *negatively* correlated with some Scholastic Achievement Tests (SAT's) (Thorsland and Novak, 1974).

Genetic and environmental factors

For centuries there has been controversy over the question: What is more important, nature or nurture? We know now that the answer is that both are important. Most people (i.e., all but the organically brain damaged or emotionally incapacitated) are capable of learning most ordinary school subject matter. There will be both genetically and experientially *rate* limiting factors, and hence accommodation for differences in learning rate is crucially important. This is why the importance of *individualized* approaches to instruction should be stressed. We also know that superior instructional practices generally result in a greater spread in achievement, so we should not expect improved teaching to achieve educational egalitarianism. Nevertheless, we can expect everybody to master a wide enough array of concepts and methods of using concepts so that human activities can have the rational basis Toulmin describes in *Human understanding*.

Affective learning

Unlike cognitive learning, the source of information for affective learning lies within the individual. However, some form of affective response always accompanies cognitive learning and thus we can influence affective learning only indirectly.

One of the most important affective responses is the positive reaction experienced when an individual recognizes that he has meaningfully learned new information, especially when the new learning results in successful problem-solving. This positive emotional response provides motivation for new learning and, because of its origin, it is referred to as *achievement motivation* or cognitive drive motivation. A form of achievement motivation is also produced when psychomotor tasks are mastered. There are other forms of affective experience that produce motivation which will not be described here, for it is essentially achievement motivation that provides the continuing desire to learn for the satisfaction of learning.

If achievement motivation is recognized as an important consequence of teaching, one is compelled to consider those instructional practices that are most likely to produce successful meaningful learning. This will be an important factor in instructional design as indicated later in this chapter.

In addition to the positive affective influence resulting from meaningful cognitive learning, we can and should seek other ways to provide students with positive affective experience. Carl Rogers (1969) and others have emphasized that a teacher who is viewed by students as accepting their interests and their worth can have a strong positive influence on cognitive learning and on students' affective growth. This is an area where much progress is needed in schools and colleges. Too often the authoritarian posture of the teacher leads to negative attitudes in students toward both the teacher and the subject matter. Students striving to maintain their ego image of personal adequacy are forced to reject an attack on their self-perception such as is usually engendered by authoritarian teaching. In a study of outstanding secondary schools in the United States, Novak found an emerging trend toward more "humanistic" educational practices that foster co-operation between students and teachers through shared involvement in selection of learning materials and evaluation of learning success (Novak, 1972). There is no substitute for the warm, accepting, human teacher if we seek to achieve strong, positive affective growth in our students.

Value learning

The acquisition of *values* is a composite of cognitive and affective learning. The values we hold are in part a function of the concepts we have. This is true both for an individual and for a society or sub-culture. This definition of values can be seen in operational form in the changed

societal values regarding pregnancy and birth control as new knowledge has become available in the past half century. Because an individual's values are rooted in the totality of his cognitive and affective experience, they are not easily modified, positively or negatively. The best avenue for influencing students' values is through planned cognitive learning experiences where the student experiences success. The best way to change students' values regarding the importance of maintaining environmental quality is to optimize learning successes for those concepts which are important in understanding the dynamics of our environment.

The parsimony of Ausubel's theory

There are more than a dozen theories that deal with some aspects of cognitive learning. Ausubel's theory is characterized by the succinct way in which it accounts for most of the cognitive[1] factors crucially important in school learning. The basic idea of progressive differentiation of concepts in cognitive structure and the facilitation of learning that derives from these concepts serves to explain most of the phenomena that should be of central concern to teachers and to students for all age levels. No other learning theoretical framework has at once such basic simplicity and such comprehensiveness. From the history of science, it is clear that the most succinct theories usually are the most productive of new knowledge. Certainly the advance of cell theory and DNA as the molecular structure of the gene stand as two classic examples of succinct explanation that have had value in biology.

CURRICULUM AND INSTRUCTION THEORY

It has already been noted that the major biology curriculum projects of the past two decades have placed central emphasis on the updating of content and on 'discovery' or inquiry approaches to learning. To be sure, there has been an enormous advance in knowledge in biology. However, to substitute memorization of cranial nerves or class and phylum characteristics of plants and animals with the memorization of the structure of amino acids or definitions of newer terms in ecology or neurobiology does not profit society to any appreciable extent. And if the 'inquiry approach' which was to characterize laboratory work (albeit, few classrooms practiced it rigorously) was limited on *a priori* grounds, it is no wonder that the results of the new programme have been less than encouraging (cf. Travers, 1973; Novak, 1974). According to Novak the principal deficiency in past instructional programmes in biology has been the lack of careful delineation of concepts to be taught and of any deliberate effort to select instructional materials that optimize the student's opportunity for meaningful learning of these concepts. Modern learning theory indicates that concept learning should be the focus of attention, and it will be shown how the curriculum and instruction theory of Johnson (1967) complements this view.

Johnson's model for curriculum and instruction

One of the important contributions Johnson's (1967) work has made is to distinguish those aspects of education that deal primarily with extracting knowledge from the disciplines from those aspects which focus on presentation to learners. The former, which Johnson identifies as *curr-*

1. Once again it is important to note that the affective experience of students is intimately related to the extent of their cognitive learning successes. Thus, a theory of learning that can augment the quality of cognitive learning experience necessarily has implications for positive affective learning.

iculum issues, include the process and criteria for selecting and ordering the knowledge, skills and attitudes to be taught to a given audience; whereas the latter are *instructional* issues, and include selection of the best examples, teaching modes and instructional settings. The most important aspect of curriculum development is the selection and ordering of *concepts* to be learned. This most important aspect of instructional development is to select the *examples* or activities which will be *meaningful* to the target audience (i.e., which will best relate to the framework of concepts in their cognitive structures).

The significance of Johnson's model is that it allows us to avoid the trap of confusing the process of extracting knowledge from a discipline with the process of selecting good instructional approaches. It was frequently assumed in the past that because a given instructional strategy or set of examples failed to teach a concept to the majority of the class, that concept was 'too difficult' for that class or age group. There is a growing body of evidence to indicate that some reasonable degree of learning for almost any concept[1] can take place if proper instructional sequences are provided and examples and activities are used that will relate to the prior experience of the learner.

The work of Piaget and his followers has shown that some kinds of abstract concepts are difficult for children to acquire before the age of 12 or 14 years. Unfortunately, Piaget's work has been misleading in that it suggests that young children cannot engage in abstract thinking, whereas this is true only for the types of concepts tested in Piagetian interviews which require a broad base of relevant experience and subordinate concept learning. Recent studies have shown that 80 per cent or less of adult population also fail to perform some of these tasks, but the most succinct explanation is not that these adults lack the capacity for 'formal thinking' but rather that they lack the relevant framework of specific concepts needed to perform the tasks (cf. Novak, 1974, 1975). Ausubel's theory of progressive differentiation and integrative reconciliation of concepts in cognitive structure accounts nicely for both the failure of some adults 'to conserve volume or weight' and the fact that a significant percentage of young children can perform these and other 'formal' thinking tasks. Ausubel's model explains not only how spontaneous[2] concepts are learned but also how we can alter educational experience to augment the acquisition of specific concepts in any discipline.

Fig. 2 shows schematically the key ideas in Johnson's model. Curriculum concerns are shown on the left of the diagram and instructional concerns are on the right. Evaluation provides feedback information for modifying both the curriculum and the instructional decisions, as well as providing feedback to the individual learner.

THE ROLE OF CONCEPTS IN BIOLOGY TEACHING

Ausubel's learning theory and Toulmin's epistemology demonstrate that concept learning is central to the development of an understanding of the biological world. Johnson's model for curriculum and instruction can be employed usefully to distinguish between the curriculum process involved in selecting concepts from biology and the instruction processes involved in selecting meaningful examples and activities. For example, the concept of the cell as a basic unit of biological structure is one that might be taught at any grade level. However, young children's motor skills are such that we usually do not offer instruction with microscopes much before the intermediate grades. There are also practical limitations regarding the financial support

1. Bruner's (1960) statement is now recognized to have been too categorical, for only under special circumstances can any subject "be taught effectively in some intellectually honest form to any child at any stage of development".

2. Vygotsky (trans. 1962) distinguished between 'spontaneous' concepts which children acquire in the normal course of maturation and "scientific" concepts which are learned formally, usually in schools. This has been a source of controversy, but Vygotsky's death in 1934 ended his contribution, whereas Piaget is active today; both were born in 1896. Most educators who follow Piaget fail to recognize the important distinction between learning of spontaneous and scientific concepts.

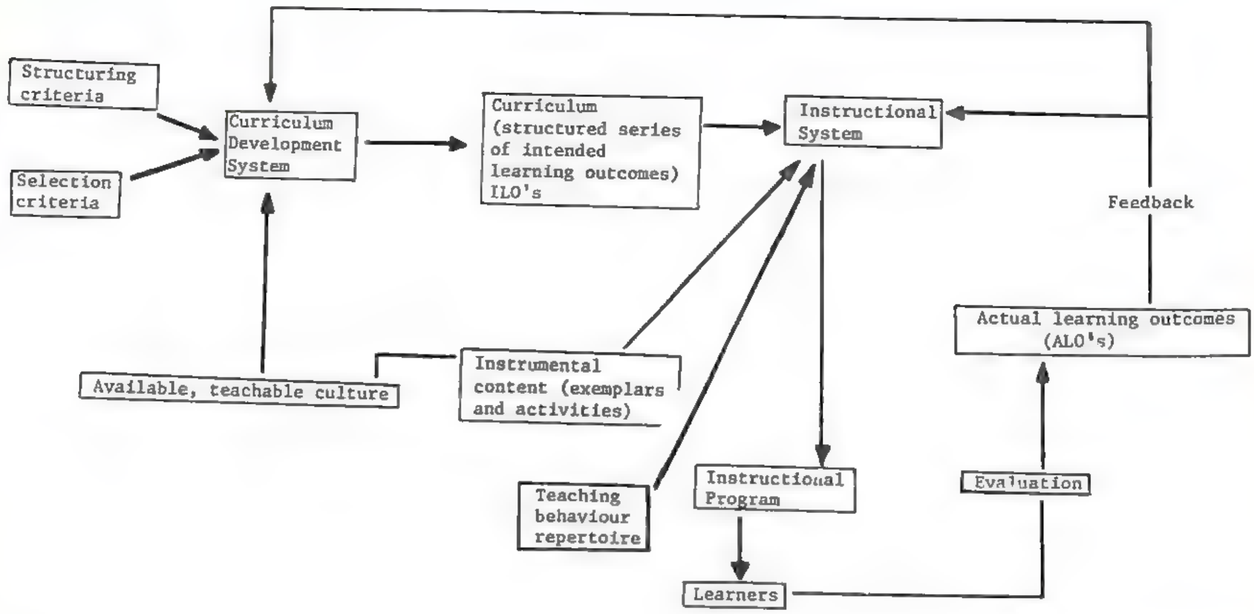

Fig. 2. A simplified version of Johnson's (1967) model for curriculum and instruction. The curriculum development system (left side) is distinguished from the instructional system. Evaluation provides feedback on the extent to which "intended learning outcomes" (ILO's) are achieved by the learners as "actual learning outcomes" (ALO's). The curriculum and/or instructional programme can be modified accordingly.

for elementary school science and the average teacher's ability to guide instruction in cell study. Therefore, the study of cell concept is postponed for reasons of instructional difficulties, and not because of the limitations of children's learning capability, as parents who have purchased microscopes for young children well know. Even at the college level, students' concepts of cells as highly organized, controlled, energy transfer systems develop slowly through carefully selected experiences.

The cell concept example also shows that knowledge is hierarchically organized. Fig. 3 shows some of the subordinate concepts and some of the relationships between concepts. For most instructional sequences, it is best to begin with the most general, most inclusive concept. The reason for this is that the general concept can more frequently and easily be related to existing concepts in the learner's cognitive structure, especially if carefully selected "cognitive bridges" are used. One could begin the study with the obvious green colour of most plants and move through a succession of questions and observations to show that the green pigment is enclosed in small bodies (chloroplasts) within larger bodies (cells) and that the chloroplasts serve as light energy converters. If one were to follow the learning model of Gagne (1970), one would indeed begin with the smallest, most specific concept and move to the most general. Obviously this is seldom an expeditious routing, but one should recognize that progressive differentiation and integrative reconciliation of concepts requires that one move both from the more general to less general concepts and also in the reverse direction as one plans the instructional sequences. This is shown schematically in Fig. 4.

Laboratory and field studies serve two important roles in biology teaching. First, experiences with real objects are needed to form *primary concepts*, e.g., to give meaning to such concept labels as cell, mitochondrion, photosynthesis, buffer, food chain and climax vegetation. Once these primary concepts are established to some degree of cognitive differentiation, they can be used in new combinations to form *secondary concepts*, e.g., ecosystem, evolution and metabolism. Piaget correctly stresses the importance of "hands-on experience" for children, but

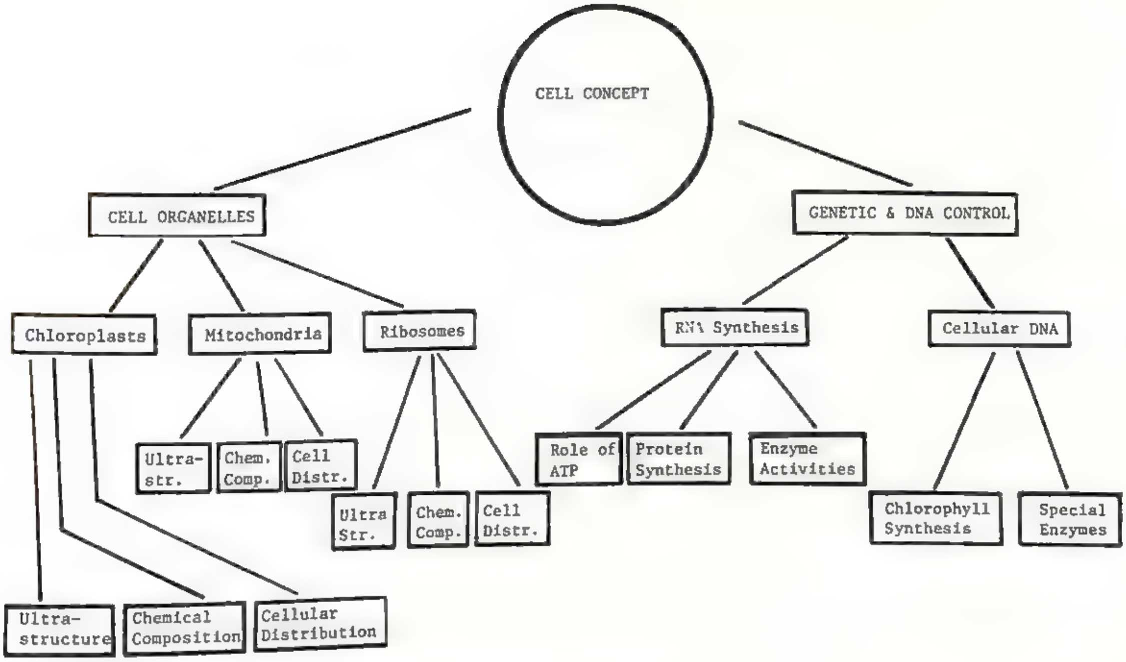

Fig. 3. Conceptual hierarchy for the Cell Concept.

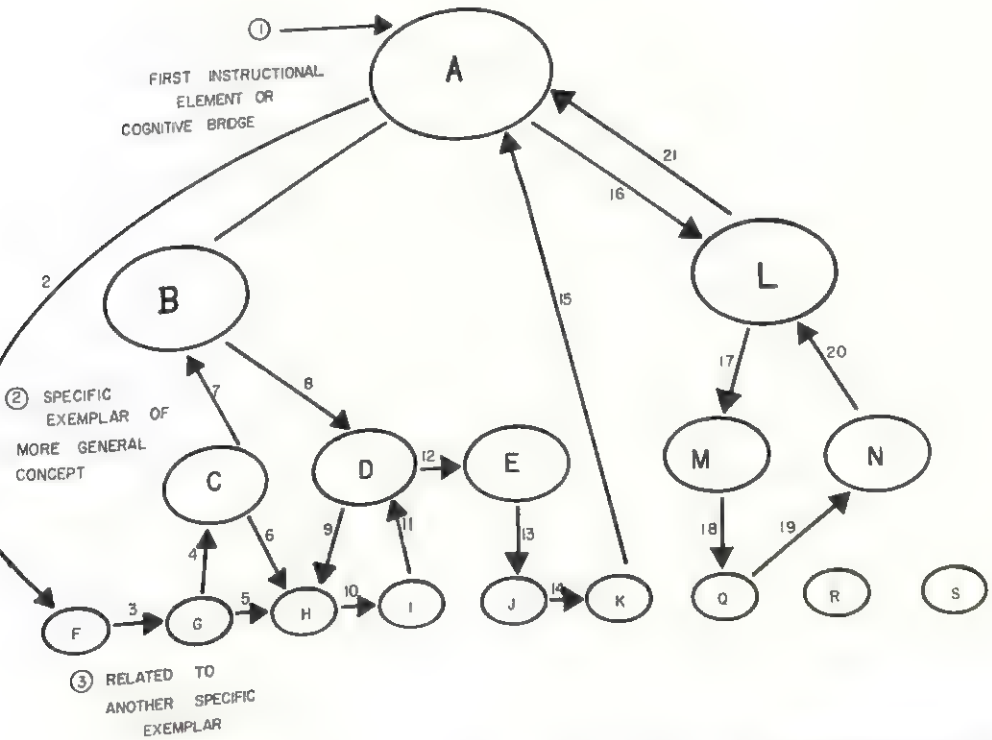

Fig. 4. Schema of a conceptual hierarchy (letters) showing instructional sequences (numbers) to achieve progressive differentiation of higher order concepts and integrative reconciliation of concepts.

such experience is needed at all age levels whenever *new* primary concepts are to be learned. However, older children may require substantially less concrete experience than, say, elementary school children since their greater range of past experience permits them to discern essential attributes of events or objects that are necessary for primary concept development. It is true, of course, that this apparent "sophistication" is sometimes unreal, and hence high school or college students will do less well than children when they are given materials from which they should derive primary concept meanings. The result is that both their primary concepts and the derivative secondary concepts are faulty and can be misleading in subsequent learning and/or solving.

The second important benefit of laboratory and field studies is that this kind of experience can easily be designed to test for concept meanings. As new objects or instances of biological processes are presented, students have an opportunity not only to differentiate concepts further, but also to test the clarity and meanings of their concepts. The national curriculum projects rightly stressed the important role of laboratory and field study for *enquiry* learning (cf. Schwab, 1962) and problem-solving experience, but they failed to recognize the central role of concept learning from which other desired behaviours derive.

A third important role for laboratory and field experiences is the social exchange that can take place and lead to positive affective development and co-ordinate growth in positive values. However, these aspects are not restricted to laboratory and field work; the latter simply provides golden opportunities to encourage positive affective responses when skillfully planned. As affective development and value learning become increasingly important in our schools, we are likely to see the important role of problem-solving experience subordinated in laboratory and field work to the development of positive attitudes and values.

A SPECIFIC EXAMPLE—APPLYING THE THEORY

Ausubel's learning theory places the central focus of instruction on *concepts.* It is also important to consider for each lesson 'what the learner already knows,' i.e., the concepts the students have that are relevant to a new learning task and the range of differentiation (or development) of these concepts. Gifted teachers have intuitively recognized these facts. One approach used by the gifted teacher is to show some phenomenon or object and ask the students, 'What do you know about this?' More explicitly, the approach translates thus:

1. Show events (things or phenomena).
2. Ask or have students record what they observe (identify the pertinent *facts*).
3. Explain what is going on (apply concepts that explain the regularities in the observed facts).

To use an example familiar to biologists, let us consider the demonstration of bubbles emerging from an *Elodea* plant in an inverted test tube with water and a variable light source. Students observe and record these 'events'.

1. green plant (submerged in water in inverted test tube);
2. bubbles rise
3. water;
4. white light of variable intensity;
5. bubbles more numerous with more light.

Now we ask them to see what *concepts* they have that explain "what is going on here". This might be done in a discussion teaching format and we can record on the blackboard:

Facts	*Explanatory concepts*
1. green plant	green plants are capable of *photosynthesis:*
2. bubbles	some gases (e.g., oxygen) are not very *soluble* in water (solubility concept);

3. bubble rise — gases are less *dense* than liquids (density concept);
4. bubbles increase with light intensity — *rate* of photosynthesis is dependent on light intensity;
5. bubbles are spherical — *cohesive* and *hydrostatic* forces operate.

Some students will suggest that we see *oxygen* bubbles rising in the test tube. We must ask, "How do you know that?" They certainly cannot know that the bubbles are oxygen simply by observing the *events* they see. They *infer* that the bubbles are oxygen by applying the *concepts* they know; e.g., photosynthesis results in oxygen production and oxygen is not highly soluble in water. Of course, some students may not know or may not recall that oxygen gas is released from green plants undergoing photosynthesis. Some students may inquire as to where carbon dioxide comes from and whether or not CO_2 may become "used up" at some point. We can enter a discussion of *rate limiting factors,* and this in itself is an important relevant concept.

It should be clear that a discussion centred around this simple demonstration could do much in helping teachers (and students) to clarify what concepts they already have that are relevant to studies in plant metabolism, or more specifically, photosynthesis, and also to make some estimate of how *differentiated* these concepts are. Do the students see connexions between the concepts noted above and do they see how these concepts explain the events they observe?

We could go on asking questions about rate of bubble production if the temperature is raised or lowered (enzyme action concept); if the light is changed from white to red or blue (electromagnetic spectrum–photon energy concept); where oxygen comes from (photolysis concept); the form of CO_2 in water (ionization and equilibrium concepts); etc. Since all scientific knowledge is related (i.e., belongs to the same mass of interconnected conceptual structures in cognitive structure), we can 'spin out' from a single good demonstration to explore the whole scientific cognitive framework of our students. They need to recognize this also, and to see how growth in understanding of one concept or a set of concepts (i.e., *meaningful* learning) influences the development and potential use of a much larger area of cognitive thought. In this example Ausubel's principles of progressive differentiation of cognitive structure and integrative reconciliation of concepts in cognitive structure are operating.

It should be obvious from the above example that most teachers, textbooks and course syllabuses do little to make explicit the concepts needed to interpret events and the complex interrelationships between concepts. The opposite is more often the case, where an inordinate emphasis is placed on *observing* the events and on methods for recording the observations. The fact that concepts are what we think with, what we must develop and use to explain the regularities in our observations, is seldom stressed in biology teaching. Overwhelmed with a mass of observations, descriptions or definitions, most students know of no recourse other than to memorize by rote as much as they can. The sequence: observe, memorize, test, forget becomes the common practice, rather than: observe, apply concepts, interpret, interrelate to larger concepts, solve problems (cf. Novak, 1970). Biology teaching/learning as practiced in most schools and colleges now falls far short of the potential which can be achieved if Ausubel's theory of cognitive learning is applied.

Turning to Johnson's (1967) model for curriculum and instruction, the example given serves to illustrate the importance of distinguishing between the curriculum task of selecting concepts to be taught and the instructional task of selecting the examples and teaching strategies. Usually the "*Elodea* in a test tube of water" example is thought of as a demonstration of the concept *photosynthesis.* However, this example simultaneously involves numerous other concepts. It will serve as a good illustrative example of photosynthesis *only* if the students possess *some* degree of development of other concepts. In the same way, a *Coleus* leaf exposed to light illustrates starch accumulation (from photosynthesis) only if many other relevant concepts are understood to some degree. The *selection* of examples to teach concepts and the *sequence* in which the examples are presented therefore involves a complex series of decisions, and con-

siderable trial-and-error. This is one of the reasons why discussion teaching approaches can be helpful. Individualized instructional approaches which allow flexibility in choice of learning material, varying lengths of study time and tutorial assistance are one promising way to incorporate the best of what we now know about learning and teaching (cf. Postlethwait *et al.*, 1972). Instructional modules (cf. Creager and Murray, 1972) will undoubtedly become an increasingly popular approach to biology teaching when their design incorporates the kind of theoretical considerations presented here.

SUMMARY AND RECOMMENDATIONS

Concept learning is the most important aspect in the design of effective biology instruction. While affective or emotional growth is also regarded as important, this form of learning is largely concomitant with cognitive learning and is likely to be positive and enhancing to an individual when cognitive learning experiences are positive. Values are defined as a composite of cognitive and affective learnings, and since the latter are closely bound to the former, cognitive learning is seen as the principal avenue for achieving changes in values.

The central role of concepts to society and for what Toulmin (1972) has called *Human understanding* was also discussed. Concepts are evolutionary in character, and this is also important for students to learn. A parallel drawn between the evolution of scientific concepts and the ontogeny of a student's concepts as new methods of study and new information are acquired can serve to illustrate the fluid nature of human thinking, its dependence on existing conceptual frameworks, and important affective or emotional concomitant learning. The learning theory of David Ausubel (1968) serves as a useful explanatory model to guide biology teaching. His emphasis on the central role of concept learning in meaningful learning and problem solving is now supported by a growing number of empirical studies (cf. Novak, 1974).

Previous efforts in biology curriculum design have not distinguished explicitly between the operation of extracting knowledge from the disciplines in the operation of instructional design and the selection of specific examples to illustrate concepts and methods of inquiry in biology. Johnson's (1967) model for curriculum and instruction provides a functional theoretical base for the improvement of programmes in biology. Together with Ausubel's learning theory, an adequate theoretical base exists, according to Novak, to guide more promising learning experiences for students.

It is important to note that only do courses in pedagogy need radical revision to incorporate new knowledge from learning theory and instructional theory, but basic science courses taken by teachers are also in need of significant reorganization. At all educational levels, there is a need to place explicit focus on the *conceptual organization of knowledge* and to incorporate what is now known regarding the facilitation of concept learning. It is also important that more and better research be done, based on sound theories, for many unanswered questions remain in the complex process of instructional design and improvement of learning environments.

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The impact of new instructional equipment and educational technology in the process of teaching biology

Since the 1960's the teaching of biology in most countries has developed in new directions. (See the chapter on "The development and design of new courses in secondary biological education"). One cannot ignore these without the risk of giving a purely technical description of instructional equipment, old or new, whereas a study of world literature reveals a willingness to adapt and submit the use of these means to precise pedagogical conclusions.

For a long time the teaching of biology has remained rigid and dogmatic. The teacher transmitted elaborate patterns of knowledge to pupils whose role was reduced to understanding and memorizing, the whole class moving at the same pace following a programme laid down by the teacher or the administrative authorities.

This pedagogy has changed but in an uneven way, depending on the country, and in each country depending on the institutions or the teachers. The introduction of active methods implying a more effective participation by the pupil in class activities has manifestly modified the form of biology teaching. The teacher encourages, in a more or less controlled way, the intervention and the activity of the pupil's laboratory exercises are developed and the distinction between lectures and practical work narrows and even tends to disappear. It remains true, however, that pupils in the same class, work according to a common study programme and at a pace which is identical. The teacher remains in control of the situation and strict guidelines persist, despite greater participation by the pupils.

In the course of the sixties and seventies a new stage in the evolution of biology teaching has been completed. Numerous people involved in teaching have realized that the traditional class is not a homogeneous group: aptitudes, motivation, speed in the acquisition of knowledge, and modes of structuring knowledge differ from subject to subject. The teaching of biology has became orientated towards a style of teaching that is both individualized and independent, leav-

ing each pupil, or small group of pupils, free to proceed at their own pace and to taking such steps as are appropriate to that pupil or group. The pupil is thus led to undertake his own scientific education, no longer by pursuing a linear programme centred on the mere acquisition of factual knowledge, but launching forth from precise biological problems which he himself sets and which he himself attempts to solve. Such an evolution in teaching biology, more or less pronounced in different countries, has been accompanied to varying degrees, by an appreciable change in the use of the equipment and technical means at the disposal of teachers today.

In general terms, two levels may be distinguished in the use made of this equipment.

– The first level is characterized by the fact that technology is defined as an auxiliary which has as its main objective the supply of material and services at the request of the teacher. Teaching is thus enriched and completed by a whole gamut of media; recent innovations such as teaching assisted by computer and television can be used, provided they do not radically alter the established organization of the class and programmes.

– The second level is characterized by a systematic application of audio-visual methods and the technology of education, in order to achieve a certain number of objectives: to encourage a critical attitude on the part of pupils by presenting knowledge with the aid of a supporting element which is not identifiable with the teacher, and which he learns to master himself; to free teachers, if possible, from the task of transmitting information so as to facilitate the work of animation and formation.

Thus educational technology becomes involved in new usages by modern pedagogical concepts, which often call into question pedagogical aims, programmes, the function of teaching personnel and the very organization of the class.

NEW TRENDS IN BIOLOGY TEACHING AND THE ARCHITECTURAL DESIGN OF TEACHING ENVIRONMENTS

In establishments equipped for traditional teaching through courses and laboratory work, the area reserved for biology teaching is often still divided into lecture rooms and rooms for practical work, or laboratories, organized with fixed work-benches. When the distinction between lecture and laboratory practice tends to disappear, the lecture room is more specifically reserved for operations of synthesis or editing the results obtained in the laboratory. This environmental arrangement is rigid and allows only a very limited adaptation to the new forms of teaching.

The orientation towards the independent work of pupils has led to an entirely new conception of the architectural design of teaching environments. It has proved necessary to take account of the different kinds of pupil activities, sometimes all going on at the same time, which is implicit in this new style of pedagogy:

- experimental studies pursued by small groups of pupils and possibly involving different subject matter;
- documentary work which has to be done on the spot, even in the actual course of experimental research;
- the maintenance of animal rearing facilities and of cultures necessary for research by work teams;
- restatements and syntheses, bringing together small work teams.

The teaching environments set up in several countries, where account has been taken of the pedagogical needs described above show a breaking up of the traditional class. Lecture rooms and rooms for practical work have banished and given way to open structures, broad areas with no partitioning, or very little, in which sectors of activity are organized, the pupils circulating freely from one sector to another: experimental sections, documentary files and libraries, sections for cultures and rearing, areas given over to the exposes of synthesis, etc. The furniture, including work-benches, is not fixed, which allows one to modify the general structure easily according to

needs.

These new structures have one essential characteristic: great *flexibility*, which makes their adaptation possible at every moment to new pedagogical demands and thus creates the material conditions favourable to the autonomous activity of the pupils.

An excellent illustration of these open structures is given in a certain number of publications, such as: *Facilities for secondary school science teaching. Evolving patterns in facilities and programs*, by Novak (1972); *Propositions relatives a l'architecture des salles de sciences naturelles*, by Giordan; *Planning in the Science Centre* by Harding and Coll.; *The design of biology laboratories for Asian second level schools*, by Sharna and coll., etc.

These modern installations, sometimes luxurious, may appear too costly for the budgets of many countries. It is nonetheless a fact that certain environments, even modest ones, if conceived so as not to fix teaching in a traditional mould, will prove in due course to be noticeably more effective than more costly but more rigid installations which preclude or limit pedagogical innovation.

Those practising a pedagogy where the pupils' autonomy is privileged are unanimous in the view that open plan, flexible structures constitute a *prerequisite* for the effectiveness of this modern conception of scientific education.

BASIC EQUIPMENT AND THE SCIENTIFIC ACTIVITY OF THE PUPIL

In order to learn science one must work like a scientist and a scientist's place of work is the laboratory and the field. Scientific work requires equipment; the concrete scientific activities of the pupils, their manipulations and experiments also require a minimum of scientific equipment.

– Tools, the material necessary for observations and experiments on living material; instruments of dissection, magnifying glasses, microscopes, animal– and plant-collecting apparatus, aquariums, terraria and physiological apparatus such as myographs, cardiographs, chemical materials, glassware, etc.
– Living material (animals and plants), collected from nature, reared or cultivated in class or in a specific space reserved for the purpose within the perimeter of the educational establishment.

All this equipment is indispensable whatever pedagogical methods are followed (traditional or more modern teaching). Without it, the teaching of biology is an expression of purely oral or bookish knowledge whose educational value is virtually nil.

Although this fundamental apparatus is present and available, sometimes in liberal quantities, for pupils in numerous countries, there are other countries where many education establishments, in particular at the elementary level, in the first cycle of secondary teaching and in the remote rural areas, are totally without such aids. Despite the financial sacrifices imposed elsewhere in the education systems, the financial resources of the establishments or of the State do not allow them to provide pupils with the minimum essentials in scientific equipment. This is a serious situation and raises the dilemma of how to teach biology correctly without any equipment. Before introducing into certain countries sophisticated and sometimes very onerous techniques of teaching, it would be advisable first and *as a priority*, to find suitable, inexpensive and rapidly applicable solutions to this problem. The following suggestions, for example, might be envisaged:

1. The dissemination in the countries concerned of information about investigations carried out by certain institutions or individual teachers in order to devise varied and inexpensive materials for teaching, materials which can be assembled by any reasonably skilled teacher. The *Guidebook to constructing inexpensive science teaching equipment* by Lockard (1972) lists simple techniques for building numerous tools and apparatus which meet all needs in biology teaching (90 items are described). The *Principes de la methodologie pour les classes du premier cycle* by Terrible (1967) illustrates, with examples, how to produce effective scientific apparatus from waste or salvage materials: plastic bottles, wrappings, old planks, ball pen cases and refills,

scraps of sheet iron, wire, etc.

Widespread dissemination of these procedures, encouraging teachers to use them and to think of others, would perhaps offer a palliative, given that absence of equipment which so seriously restricts biology teaching in certain developing countries.

2. The creation of *Centres for scientific equipment* on a national or regional scale to mass produce low-cost materials although these may require the use of tools which schools do not necessarily possess. Moreover, local production would mean that financial resources, already very limited, would not be diverted, as is sometimes the case, to the purchase from industrialized countries of expensive material which requires difficult maintenance and is very often unsuitable to local needs.

The presence of living things in the school situation and their use in the teaching of biology are clear necessities in the scientific shaping and general education of the pupils. But divergent conceptions appear, depending on the countries concerned, about the pedagogical use to be made of these living things in the scientific formation of pupils.

The pupil-living material relationship which allows for the acquisition of knowledge and the development of scientific behaviour is not envisaged in the same way by all teachers. For those who, following Piaget, consider that a child passes through a number of stages of acquisition linked to a *direct* and totally *independent* experience, the young pupil must be put into contact with numerous and various living things without these being part of a "learning process" as such. The permanent presence of living things in the classroom must enable the pupil to acquire *directly,* starting from personal experience, a certain number of concepts, For others, relying on a more traditional pedagogy, the participation of the teacher, whether in a directing role or not, is necessary for the acquisition of structured knowledge. Biology teaching must therefore be provided and organized for the young pupil since his free participation, while necessary is not considered sufficient for a coherent scientific education.

While teachers, in spite of everything, are unanimous in considering that the presence of living things in the framework of the school situation constitutes a definite benefit to the pupil, trends differ at the practical level. Must one bring as many animals and plants as possible into the classroom, which is the environment of the pupil, or should one try to send pupils outside the classroom situation to the maximum extent, so that they may find this contact with living beings in nature? Here too, opinions differ appreciably.

The use of living creatures,[1] whatever the teaching methods used, leads again to the problem partly raised earlier, namely the architectural design of teaching environments which can be adapted to this purpose. The available literature provides scarcely any information on the difficulties and their solutions (but see *"Facilities for secondary school science teaching"* by Novak). These difficulties may be grouped under two general headings: those which concern the specialized installations within schools and those which relate to specific arrangements made outside these schools.

1. How, *when they exist,* are the locations where rearing of animals and cultivation take place *within* the confines of school buildings organized? Are their arrangements and their relation to other teaching structures favourable to modern methodology in biology teaching and compatible with the autonomous activities of the pupil? Can experimental breeding and cultures carried out by the pupils be maintained for several days, or even weeks, and under what conditions?, etc.

2. Within the establishments' perimeter, but outside the buildings, are areas of ground

1. The techniques for capturing or collecting living things, rearing them, and utilizing living organisms for the study of precise themes, have been deliberately left untouched in this chapter. Detailed documentation on these subjects will be found in the work of Wray (1974), *Recommended practice for school relating to the use of living organisms and material of living origin,* and in that of Deunff, *Scientific activities to arouse interest for children from 5 to 11 years.*

placed at the disposal of teachers and pupils in order to carry out cultivation and/or experiments? Has an uncultivated garden (with or without pond) where the flora and fauna develop freely, been put aside for their use? What are the characteristics of these areas and what difficulties are encountered in the allocation of duties among biology teachers, etc.

Replies, or partial replies, to these questions would enable us to define the needs in respect of apparatus adapted for the use of living beings and solutions which would allow them to be met.

DEVELOPMENT OF THE UTILIZATION OF AUDIO-VISUAL TECHNIQUES IN BIOLOGY TEACHING

These techniques are many and varied. The words of the teacher, the book, the blackboard are the earliest forms and are still in use. But since the end of the 19th century and the beginning of the 20th, photography, the cinema, radio and television have offered, at an ever-increasing rate, new means of information and communication from which teaching, and in particular biology teaching, could not remain aloof.

Current visual auxiliaries in biology teaching

Visual auxiliaries, some of them relatively cheap, are currently used at any rate in developed countries, no matter what style of pedagogy may be adopted (traditional teaching in grouped classes or individual instruction). These mainly take the form of mural posters, over-head projectors replacing the blackboard, photographs on paper, slides, 16 mm or 8 mm films, silent or with sound track, and video tape cassettes, the latter replacing cinematographic films.

These auxiliaries are the visual substitutes for reality, or processes of analysing reality, the use of which is only acceptable where the real objects are not accessible to the pupils. In a general way, the use of visual methods is essential when the message can only be transmitted by these means. The static pictures (photographs, slides) allow one to show objects which cannot be observed directly or, by concentrating their attention, enables pupils to analyse the details of an organism not easily examined directly. Films are irreplaceable as an instrument for analysing dynamic phenomena; in particular the use of slow motion (for the movement of animals) and rapid motion (growth and movement of plants) convey a knowledge of movement where the natural rate is either too fast or too slow for analysis.

Because of its relatively reasonable cost, its technical quality and its great flexibility of use, 8 mm film, and above all super-8 film, are used more and more, while 16 mm film is used less and less. In particular, super-8 film showing a single concept (single concept film) generally silent and lasting only a short time (3 to 6 minutes) tend to be widely used. The single concept film can be seen several times within a short period and, if need be, stopped at a specific frame; it is frequently used as a 'datum', or starting point, for active study by pupils, just as they would study a real biological object.

The interest of these visual techniques in biology teaching is universally recognized. Nevertheless, enquiries carried out in certain developed countries have revealed squandering of funds in the installation of sophisticated and complex equipment conveying merely trivial messages, or rather, information which less expensive means such as a simple blackboard, for example, could have conveyed equally well. This wrong use of technology, already deplored in industrialized countries, takes on a much more serious aspect in countries where financial resources for teaching are limited.

Individualized instruction in biology by multi-media (audio-tutorial system)

It is in the English-speaking countries (United States, United Kingdom, Australia, etc.) that maximum use is made of the media, in the context of autonomous work by students, mostly at univer-

sity level and at the senior level of secondary schools.

This new form of biology instruction, developed as a result of the experience of Postlethwait and his colleagues at Purdue University, is known as the *audio-tutorial system* (ATS). The ATS was conceived and installed for the teaching of plant biology by Postlethwait in order to cope, on the one hand, with a large number of students whose comprehensive instructional framework exceeded the resources of the teaching personnel available, and, on the other hand, with the heterogeneous nature of this particular student body. It was subsequently extended to other universities and also to certain classes in the senior level secondary schools.

This type of totally individualized instruction is based upon the use of multi-media (tape recordings, slides, 8 mm films or video-cassettes, guide books) which provide each student with the scientific information and the guidance needed for practical activities (observations, laboratory work and even field exercises). The general organization of instruction by ATS is as follows:

The course is fragmented, programmed, in a series of "modules" or "mini-courses", each corresponding to a precise theme. For each "module" the students take part in three kinds of activity.

1. Independent work in an audio-visual booth (a booth can be occupied by only one student at a time). The equipment in the booth, utilized as desired, generally consists of a tape-recorder with headphones which transmits the course and the guide instructions for the use of other media and for practical exercises, a slide viewer, an 8 mm film projector and material for observation and experiment.

For each module, a guide book is available to students but the continuity of the work is maintained essentially by the taped commentaries.

An important aspect of ATS is the more extensive use of live material easily accessible to students; this allows for complete integration of experimental work and theoretical information.

The time spent on individual work in the booth varies and is left to the discretion of the student; on average it amounts to four hours per week for a single module.

2. Sessions in small groups bringing together ten or so students and a teacher (One hour-long session per week). There are seminars where an exchange of ideas takes place, with questions and answers, on a module related to the study previously carried out in the booth.

3. General sessions, bringing together several hundred students and a teacher, reserved for general reviews and syntheses.

This form of instruction backed by multi-media has certain advantages, but also certain drawbacks.

The advantages most often quoted in the literature are the following:

1. The student is *autonomous* and works at his own pace. The system allows for the *repetition* of audio-visual information according to the particular needs of each student.

2. The learning process takes place through an association of ideas, of objects and of appropriate situations. This association is achieved by gathering together into the booth all the objects, scientific apparatus and audio-visual means necessary for a particular form of instruction. A *reinforcement* effect makes the instruction more effective.

3. The ATS allows maximum integration of learning activities. Teaching is no longer dispersed into lectures, practical work, and field work. All these activities are simultaneously implied and consequently closely integrated.

The defects are more difficult to discern. Some of them, however, may be identified as follows:

1. Certain students get lost because of the variety of apparatus, the use of which and the combinations of which they are unable to master. Others find the permanent utilization of the tape-recorder tiresome and monotonous.

2. The most fundamental defect concerns integration of the knowledge acquired in the different modules into a coherent and synthesized whole. The system is criticized for fragmenting concepts and making access to general and fundamental ideas difficult.

3. The system is expensive: in 1973, the installation of a single booth with apparatus came to about 400 U.S. dollars.

The effectiveness of the ATS and of similar systems has given rise to a certain number of evaluations. A first appreciation can be made from the reactions of teachers and students. They are in general favourable when the programmes are well designed. A more precise evaluation can be obtained by comparing at an intellectual level and in respect of the same subject, the performance of identical groups, one of which has received instruction through media and the other through conventional teaching. According to certain authors (Marinos and Lucas, 1970) no significant difference is observed between the two groups, whether in terms of mastery of knowledge or the acquisition of a superior experimental efficiency. For others, on the other hand (Meleca, 1970; Brewer, 1974), the group of students who have followed the ATS teaching system is superior to the control group of equal intellectual standard. In general terms, the evaluations made are favourable towards ATS, with the reservation that the programming and combined use of media should be carried out in perfect conditions. Finally, there are those who consider that, despite the qualities and efficiency of ATS it would be dangerous to make it a fundamental teaching method in biology. Its visible shortcomings must be subject to rectification by other types of formation. "The ATS is *one* method, but it is not *the* method of teaching" (Marinos and Lucas, 1971).

Radio and television in biology teaching

The use of these media, widely practised in the industrialized countries during the sixties, now seems to be in abeyance. Radio and open-circuit television, of necessity rigid and by nature dogmatic, are difficult to use in a pedagogy geared towards the autonomy of the pupil and the individualization of instruction. Even closed-circuit television is sometimes abandoned: in the United States, more than one hundred schools fully equipped with televisual resources, no longer use this form of instruction. It nevertheless remains closely integrated with normal biology teaching in certain countries but, it seems, only in experimental establishments (France).

Paradoxically enough, the utilization of radio and television, despite the increased cost of the installation and maintenance, is fully justified and effective in developing countries. The lack of suitably trained teachers, the need to reach not only school children but the whole population when it is a matter of general education (health education, for example) necessitates the use of media able to reach a widespread audience. It must not be forgotten that, in a fair number of these countries, the press is underdeveloped and sometimes non-existent, and that very often there is a high level of illiteracy. On the other hand, radio receivers exist in all the villages and radio is often the sole means of communication and of information.

Precise cases of systematic utilization in developing countries of radio and television for biology instruction clearly demonstrate the real effectiveness of these media in overcoming certain difficulties in the teaching of this discipline. Thus, to compensate for the inadequate training of certain teachers, a teaching experiment in biology by radio, and subsequently by television, was launched in Mauritius in 1969. The radio broadcasts were sent out each day at the end of the morning. An enquiry conducted among teachers for the purpose of evaluating the effectiveness of these broadcasts revealed that they were used very little by the teachers while some ignored them completely. The most frequent criticisms concerned:

- the absence of any relationship between the subject matter of the broadcasts and the school teaching programme (30 per cent only of these broadcasts were made locally, the

rest being made in the United Kingdom);
- the difficulty of integrating the transmissions into the timetable of schools which did not necessarily arrange for the broadcasts to coincide with the hours allocated to biology teaching.

The television programmes were better received by teachers. The fact that they were locally produced and well adapted to themes studied in class ought to have enabled good use to be made of them in biology instruction. Unfortunately, they were transmitted in the evening outside class hours and were followed by only 10 per cent of the pupils. The support they could bring to the teachers' work was therefore negligible.

The participation of radio and television is in certain situations irreplaceable. The Mauritius example chosen from among others, reveals the difficulties encountered in efficiently organizing, the operation and successfully carrying it out. Perfect co-ordinator between the production bodies and the users implies the establishment of centres of production specializing in education transmissions, a school organization adapted to this method of teaching, and teachers trained to work with the producers of the broadcasts who must also be expert teachers.

In a very different pedagogical situation, another example of the effectiveness of teaching essentially backed by television has been provided by the Institute of Agricultural Technology of Mostagenem in Algeria. This Institute has been created to train, before 1980, 5,000 to 6,000 technicians in rural work, who are indispensable to the success of the agrarian reform and whose training until now was not carried out. For this reason, the Institute has had to build up a system of *mass instruction* by first receiving each year a batch of 500, and subsequently a batch of 1000 engineer students. Space did not enable them to have more than 25 students together in any one lecture hall and the small number of qualified teachers precluded formal .teaching. A teaching course entirely conducted by closed-circuit television, alternating with periods spent in the rural areas appeared to be the only way to conduct this training. For the promoters of television, the use of this media also fitted in with pedagogical policy: it was a matter of radically changing the teacher-student relationship so as to make students gradually undertake their own training, in a responsible way, thus learning to collaborate among themselves and to master the different sources of information. Although an evaluation of the effectiveness of the single audio-visual backing was not made, a global evaluation of the training of these technicians is furnished by the results at the Institute's final examination. The jury, composed of persons outside the Institute, refused the diploma to only 6 per cent of the students. This large-scale media-type teaching can therefore be considered a success. The sending of numerous missions to Algeria by countries confronted with similar problems in training agricultural personnel is also evidence of the effectiveness of this type of training.

In countries where the educational structures are highly developed, radio and television constitute a form of added support to normal teaching. But in countries where, because of a lack of resources, a classical type of teaching does not allow a response to certain vital training needs, the use of radio and television proves to be an effective instrument.

TEACHING BIOLOGY WITH THE HELP OF COMPUTERS

Learning with the help of computers, called *computer-assisted instruction or CAI,* developed towards the end of the sixtiesin the United States, and on a smaller scale in Europe, opens up an immense field to research and to the applications of pedagogy. Among thescientific disciplines, the teaching of mathematics in particular but also the teaching of physics and biology have brought about teaching experiments utilizing the possibilities of the computer. Programmes have been perfected and have become operational principally in university instruction (sciences and medicine) but equally, in certain cases, in instruction of the seminar level of secondary education.

The simplest use made of the computer consists of employing it as a mechanical means of testing by question and correction, with traditional instruction (lectures, laboratory work) preceding its use. The computer here plays the role of examiner, and does it efficiently since it can guide and assist the student. The dialogue consists of a programmed sequence of questions allowing each student to control and reinforce his knowledge (Andrieux B., 1971). Yet the computer can best be used for genuine instruction. In this case, the principal objective is not to transmit factual knowledge but to bring about a progressive training of the student in logical reasoning and in the acquisition of experimental methodology. In these conditions, the use of the computer achieves a form of training which is in opposition to the general trend in traditional learning, namely the *memorisation* of facts, concepts and even demonstrations of experiments. The student who learns demonstrations of experiments in this way, even if he has clearly understood their logic, is not thereby trained to think for himself.

In order to attain this objective, the experiments, duly analysed in the programming, and their results are demonstrated in such a way by the machine that the student cannot solely rely on his memory to answer. Further, the experiments are generally unfamiliar to him, a fact which requires him to use his reason in studying their development, in interpreting their results in and deducing fundamental notions which must be retained in the mind. Thus Fiszer J. (1971, 1973) orientated a programme of experimental biology on the acquisition of complete notions like 'the inductive power of tissue', 'the state of determination or non-determination of a tissue', etc.

One use of computers, of considerable educational value, is the practice of *simulations* in the course of which the student freely thinks up experiments and submits them to the computer which, in return, supplies results, both qualitative and quantitative, whose exploitation and interpretation by the student are subsequently validated or criticized by the machine. The most formalized of the biological sciences, genetics and quantitative ecology, lend themselves most suitably to this method of utilization (Bitzer, 1974, in *New trends in the utilization of educational technology for science education*, Dean and Murphy, 1973; Labine and Wilson, 1973). A good illustration of a similar exercise is provided by the learning of the Mendelian laws, with the help of simulated crossing of *Drosophila* (Bitzer, 1974). The crossing of wild type *Drosophila* and their various mutants is left to the initiative of the student. The results obtained appear on the cathode screen in the shape of images built by the machine as well as raw quantitative results. A very great number of cross-breedings are possible, from the most elementary to the most complex. The results in both the figurative and numerical sense – the latter being capable of variation if the same experiment is repeated – are the starting point of active work in the statistical exploitation and interpretation of raw data, as is normally the case in actual research.

The simulation, which requires very intensive programming, is no doubt, in the present state of research, the form of learning which permits the achievement of methodological objectives inaccessible by other technical methods of instruction.

Leaving aside the investments and costs involved in the installation and operation of equipment, which are still very high, should more extensive use of the computer be envisaged at the expense of other methods of biology instruction? For numerous teachers 'a drying up, an impoverishment and a schematization of thought would result from it (the use of the computer) as well as the risk of having to reduce all biological phenomena to an aggregate of notions which are very cut and dried, very classifiable into rigid categories' (Fiszer, 1972). The achievements of biology teaching assisted by the use of the computer are still at the experimental stage and new possibilities are not yet recognized or have hardly been investigated. Computers will no doubt be utilized more and more in instruction, but in order to achieve specific objectives that only they can achieve, without being used as a substitute for the customary modes of instruction.

CONCLUSIONS

In the teaching of biology, technical equipment varies from country to country. But in any case,

and whatever the quantity and the nature of the technical resources offered to teachers, their use must always be a function of pedagogical objectives and integrated in a defined process of training (see the chapters on 'Trends in the purposes and objectives of biological education' and on 'Trends in the biological component of education at the primary and junior-secondary levels').

Thus, in a traditional class, scientific equipment and audio-visual auxiliaries are tools used by the teacher to illustrate or to stress important points during a collective presentation, while in a class where the students work as groups, progressing according to a process peculiar to each of them, all the equipment is at the disposal of the students for research, i.e., the experimental tools as well as the audio-visual aids (students can choose and freely use slides and films, for example). Such an approach is quite different from the traditional approach, as it is the student who chooses his work tools and hence the teacher's task is significantly modified; he does not select the material, nor does he decide the timing and the ways of using it. But he does provide the class with the necessary equipment and furthermore gives guidance to the students about how to use such equipment, how to collect data or the information provided by a medium, how to exploit these data, etc. In short, the choice of objectives and of the appropriate method for achieving them dictates the utilization of the equipment and of the technical teaching tools.

While in some countries, all these resources, including the most modern are generally available to institutions, in others the teacher has nothing but the blackboard. This is a real challenge – to teach biology with no equipment – but it is a challenge which can be and must be faced. Common things, salvage or waste materials can serve experimental work, they can also help in the rearing of animals and in making cultures which have a training value. Numerous examples show that thought and imagination on the part of the teacher can overcome a lack of means. There are also teachers to whom technical means are available but who prefer to build by themselves the necessary equipment with ordinary materials. Those teachers are convinced that it is very important for the effective scientific training of the student that he should conceive and implement the experimental set-up by himself.

On the other hand, it is hoped that curricula will be conceived with due regard to such a lack of means. This does not concern the teacher alone. The natural environment, the rural community where the student lives, in example, can provide several topics which imply real scientific work without the need for numerous and complex tools.

However, it is hoped that such a lack or shortage is temporary and, in the perspective of future equipment policies, priority will be given not to a technology that will facilitate the work of the teacher, but rather to inexpensive materials and laboratory apparatus, which will allow a genuine scientific activity on the part of the pupils.

SUMMARY AND RECOMMENDATIONS

The following recommendations, the number of which has been diliberately limited, have been oriented according to the principles:

- the utilization of equipment, whatever the level of technical complexity, must be a function of the implementation of teaching methods and objectives, clearly stated by the teacher or by a group of teachers;
- absolute priority should be given to the problems raised by biology teaching in situations where there is a lack of equipment;
- a distinction should be made between those recommendations addressed to international organizations and those addressed to national institutions.

These recommendations are therefore obviously linked to those formulated at the end of other chapters in this volume.

At the international level, an effective system should be instituted for the dissemination of inexpensive and effective equipment.

For countries which still lack adequate equipment in their schools, reflexion, at regional level, should be promoted in order to conceive curricula taking account of such shortages; the natural environment and the rural community where the pupils live can provide stimulating topics for study, which have a real training value and do not need specialized or complex equipment. Regional centres, planned or already existing, should give some priority to the manufacture of inexpensive equipment adapted to local needs.

At the national level, laboratory work should be an important part of biology teaching laboratory work. This should be borne in mind when schools are built and equipped. It is necessary that all children in urban environments enjoy close contact with nature, both outside the school (field work, excursions, country classes) and within the school through gardens (cultivated or uncultivated) reserved or designed for the purpose.

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Trends in techniques and criteria used in assessing student achievement in biology education

Assessment may involve listening to students, observing them in action or reading what they have written.

Assessment in a subject area such as biology differs from the highly specific tests employed by research workers and psychometricians in that it aims at testing the achievement of students in relation to a range of concepts which have been affected by the conditions of learning, the teacher, the teaching methods and the social context.

Assessment is usually preceded by some form of measurement in which numerical values are assigned to the students on the basis of some well defined procedure or set of rules. There may be some subsequent treatment of the numerical values before an assessment is produced. Standards may then be applied to the assessment in order to obtain an evaluation of the students. Thus assessment of achievement may provide useful evidence for evaluation, but evaluation may also be made without preliminary measurement.

SOME GENERAL TRENDS IN ASSESSMENT WHICH AFFECT THE SITUATION IN BIOLOGY EDUCATION

In many countries, the traditional assessment of students has been by some form of written examination at the termination of a course of study. The increase of open access to education at the secondary level and of demands for entry into tertiary education have led to increasing pressures on examination systems. Although evidence is available which suggests that many examinations are unreliable and unjust and that they counteract the more enlightened methods of education, their influence is more powerful than ever. In particular, they tend to make certain

teaching and learning practices more circumscribed and rigid even where curricula are intended to be open and unstructured. Two main trends to remedy this situation can be discerned: firstly, the application of new techniques of testing and improvement in the design of examinations: secondly, the utilization of methods of assessment other than formal examination papers.

In biology examinations, the following trends emerge.

1. There is an increasing use of objectives which are explicitly stated in relation to the educational aims of a curriculum or with the intention of providing a framework of aims where none existed previously. The main effect of this is that the assessment of students is becoming less concerned with the extent of stored information and more with thinking processes.
2. Devices which improve the quality of testing are being employed on a wider scale. Examinations designed in relation to the two dimensions of subject content and behavioural skills have improved in validity. The difficulty of producing good examinations is being recognized and some efforts are being made to promote the necessary skills in examiners.
3. New examining techniques include the use of a wider range of types of questions. Greater precision in testing is being sought by writing the material to defined specifications with a consequent development towards objectivity. This has led to a greater employment of resources in writing test material and some reduction in the human effort required in marking. A consequence of this has been some improvement in reliability.
4. In those countries where the examination system is spreading to include a wider range of student ability levels, objective tests and questions structured in specific parts have been found to be more suitable than extended essay questions. The difficulties of language expression are reduced and the inclusion of many small elements in a test provides greater reliability than a few large questions.
5. In each country changes in methods of examining are closely related to the philosophy and structure of the educational system and the state of development of the biology curriculum. Biology examiners are not necessarily in a position to make changes in examination policy. Certain changes, however, lie within their competence.

   - With laconic syllabuses, such as are often current in traditional systems, some opportunities exist for a wider interpretation of certain general principles. Alternative questions with this in view can prepare teaching institutions for impending curriculum and examination changes.
   - The introduction of non-syllabus-based questions represents a more fundamental departure from a traditional scheme. They compel students to exercise cognitive skills at high levels than recall of knowledge. More advanced forms of biology examining are achieving this by using questions which require the handling of data. In practical tests, biology offers unique opportunities for inductive reasoning, as in suggesting function from observed structures or classification based on observed characteristics.

Instead of formal examinations, some countries employ assessments during the teaching of a course, with systems for the acculmulation of credits at the secondary and tertiary levels. Although such systems are broader in scope and hence more valid than terminal examinations, their greater emphasis on regular behavioural performance can have a restrictive effect on students and teachers. Non-conforming students may be penalized and fast learners discouraged. Nevertheless, there is a strong trend towards various forms of continuous assessment. Apparently, educators are feeling the need to make a stronger relationship between the daily educational experiences in the classroom and laboratory and the assessment of achievement as it occurs.

In several countries, internal assessment and external examinations are being employed together. In the United States, there is a tendency to use externally standardized tests as a corrective to internal assessment. In France, school records may be used as a check on the external examination. Examination reform in the United Kingdom and India has included the intro-

duction of internal assessment as a component of an externally awarded examination grade. In Sweden, internally scored tests may be moderated by the central authority. In the International Baccalaureate, teacher assessments have been tried as checks on examination grades.

The drive towards open access to education for a wider range of students is in keeping with the democratization of education. The appropriate assessment of student achievement then becomes concerned with the progress of students or groups through a continuous process of education. Concepts of education at specific levels tend to break such continuity and the terminal examinations or accumulated credits used for selection at each level tend to become instruments of exclusion. Selection procedures of every kind imply competition and although this may be considered a legitimate function in competition societies, it distorts the educational function of schools. Assessment within the schools as accrediting agencies takes some of the competitive pressures off students, but where an external examining body operates the testing, the pressures fall directly on the students and teachers.

Group activities would indicate group assessment rather than individual testing. A disparity exists between the group work encouraged by educationists and the individual assessment required by some accrediting agencies. For example in the teaching of groups of mixed ability in Certificate of Secondary Education (CSE) and in co-operative biology projects in Advanced level Nuffield General Certificate of Education (GCE) in the United Kingdom, the assessor hopes to be able to distinguish individual contributions to the group, often at different levels, as part of the outcome for grading. Group assessment lays emphasis on co-operation rather than competition. This is seen by certain socialist countries as a most important aspect of moral education.

TRENDS IN VARIOUS COUNTRIES

Centralized system

Characteristically, centralized examining tends to be linked with the final assessment of courses used for competitive selection. This is generally true for the countries of Western Europe although biology ranks as a major subject for final assessment in relatively few of them. Essay-type examinations, often marked on the basis of an over-all impression, are prevalent. These tend to be related to the testing of knowledge, although in France, for example, essay questions and oral examining have moved towards the testing of science process skills. The tradition of oral examining which continues in some countries of Eastern and Western Europe is sometimes related to the testing of practical work. Objective testing has been a relatively recent addition to some well established examination systems.

A certain amount of freedom to teach biology according to local needs is possible within centralized curricula when cumulative assessment within schools forms the whole or an important part of the examination system. For example, this situation exists in Sweden and some parts of the Federal Republic of Germany where central control is used to maintain comparability of standards of assessment between schools. In the Netherlands, there is, at present, an equal allocation of marks between an external objective test and cumulative assessment. Proposals for change suggest an increase in the range of techniques used for external testing and more specific guidance for teachers in the skills to be assessed and the criteria for grading them.

The pooling of national resources in both West Africa and East Africa to form regional Examination Councils has enabled testing skills to be utilized in a most effective manner. As these regions move away from dependence on foreign-based examinations, the dual problems of local relevance and international acceptability are being investigated. Although local tertiary education is developing rapidly, many students still qualify for study overseas through final assessments at the secondary or tertiary level. The new techniques employed include objective testing and problem solving, as well as essays and practical tests. Objective testing is particularly

useful for establishing comparability between national systems provided that the problems of production can be solved. A test development unit operates within the West African Examinations Council. In Malawi, the biology examination at the middle secondary level for 1974 made use of structured questions, replacing the previous use of essay questions and objective tests. Apart from the problems of objective test production, the further problem of the use of language by students in written examinations has led to this change.

In Eastern Europe, the centralized systems have combined for a multilateral study of the problems of assessment at the Central Institute for Education Research in Budapest. Some of the problems are related to the multiplicity of personal characteristics of students and to social relationships as well as to the production of tests having a high degree of objectivity. Both objectivity and a consideration for the state of development of each student are seen as two poles of a dialectical contradiction which has to be constantly resolved anew and in which responsibility for assessment ultimately rests on the teacher. "The function of favourable evaluation is to provide incentive. Group assessment leads to development of the faculty of self-evaluation, of a group spirit and of a sense of responsibility for one's work and that of fellow pupils". Group assessment of this kind is advocated in the People's Republic of China and in Cuba. It is interesting to note that in apparently centralized systems such as these, much responsibility for assessment is undertaken at the local level, using such techniques as oral examining, regular diagnostic tests and assessments of originality and initiative in practical application.

In Malaysia, Singapore, Hong Kong and South Africa, centralized examining largely based on the British model is the prevalent pattern. Biology examinations usually consist of two written papers and a test of practical skills. These provide acceptable qualifications for overseas universities. Within this pattern there are some changes towards problem solving and, to a lesser extent, towards objective testing. This has been accompanied by a steady rejuvenation of syllabus topics, although biosocial issues are not prominent. In India, developments towards increasing assessment of practical work are shown by an allocation of 20 per cent of the examination marks for assessment of class records and collection of specimens in some instances. At the middle secondary level, topics of social relevance are of increasing importance.

Among American countries, 42 per cent were shown to have compulsory biology examinations in 1972. Objective testing is widely used in these, but there is a trend towards the use of a combination of written testing techniques. Oral testing is used in a few countries. Practical assessment is indicated in ly five countries.

Systems approved by a central authority

In the United Kingdom, the multiplicity of examination boards and curriculum developments has led to a variety of styles of assessment. For students who do not specialize further, assessment of biology at the middle secondary level (CSE and O-level GCE) is final. Written tests at this level usually consist of short structured questions and short essays, with a trend towards objective testing. With suitable accreditation (mode III CSE), internal assessment can replace external written examinations but the problems of moderation are severe. At the upper secondary level, written papers are usually based on essays and problem solving. Practical examinations are used at this level with an important trend towards cumulative assessment. The Nuffield Advanced Level examination provides a useful example of complete examination design, using a range of techniques for written tests and assessments.

Decentralized assessment

In the United States achievement testing for internal credits is the responsibility of the schools. Tests are either locally prepared or obtained from commercial sources. There has been some criticism of the excessive amount of objective testing which tends to make use of recognition-

type questions and which does not measure certain skills which essay questions can test. The interpretation of test results for evaluation of students is also a general problem. Some external control of testing appears where minimum standards for graduation are established by individual states which may be inforced by regional accrediting associations. Although final assessments within schools are unusual, institutions at the tertiary level may set their own requirements for admission. Many of these institutions use the Educational Testing Service which provides assessment in biology of 125 objective items in 1½ hour and three essays in 1½ hour. In this, there is emphasis on application and interpretation of data (Kastrinos, 1974).

The assessment pattern in Canada has tended to move away from a three hour written examination at the end of each term towards more frequent student assessment. Some provinces have discarded final assessment testing, leaving teachers with responsibility for summative evaluation of students.

In the Philippines, objective written tests are used to assess biological knowledge and the nature and methods of science. These are employed in relation to each unit of curriculum material especially for diagnostic purposes. In addition, performance assessment of practical work is carried out and affectives such as leadership, resourcefulness and preparation for biological activities may be included. At the tertiary level, there is more emphasis on problem solving.

Although an internal system of credits somewhat similar to that of United States operates in Japan, the requirement of each board of education impose a large degree of conformity. There is intense competition for entry to tertiary levels of education and the screening tests for this strongly influence upper secondary education. The Educational Test Research Institute has paid much attention to the problem. As a result, the extended use of objective testing introduced after 1946 has now been replaced by a combination of objective and essay-type tests which assess analysis, evaluation and constructive thinking as well as a knowledge of biological facts and principles.

ISSUES WHICH AFFECT ASSESSMENT IN BIOLOGY

The employment of assessment

The uses of public examination

In general, examinations are used in making decisions on the transition from one stage of education to another. This is most prominent in selection from the upper secondary to the tertiary level of education. In most countries what is selective for the few at this level is terminal for the majority. Examinations thus become devices of social restraint where opportunities for higher education are limited. Moreover, what is meaningful as a test for the vocation of a biologist is less so for those for whom biology is a component of general education. The societal uses of the examination make for further conflict with the aims of the curriculum. The public view of examination success as a means of identifying a status in society generally has little relevance to the specific achievements which have been assessed. All formal examinations have some effect upon learning. Teachers work under the constraints of the examination syllabus and students can be discouraged from further learning by examination failure. Examinations are most likely to distort the educational aims of a curriculum when the level of difficulty is appreciably higher than the ability levels of students. Teaching programmes become limited to the examination topics and objectives become directed towards the recall of knowledge.

In the face of such structures, it might well be asked what are the positive virtues of public examinations? In their favour it can be said that their prescriptive nature provides a very effective communication of the intentions of curriculum designers to teachers. They can be used to guide biology teaching in directions necessary for national development. They also provide the

standards of achievement which are necessary to ensure public confidence in biology teaching. Properly administered, they reduce opportunities for bribery and patronage in obtaining places in higher education where there is restricted access.

Public examination systems can form part of educational activities which involve international co-operation and development. Examples of this are seen between the USSR and socialist countries of Eastern Europe and between certain West African countries.

The operation of achievement tests

Niemierko has characterized a school achievement test in the following manner: it is a collection of separate tasks; it presents the subject matter in such a way that it is possible to determine the extent to which it is mastered by the student; it is used during the course of instruction. His reference to mastery implies that a student's performance is judged against a set of previously specific criteria. The development of instructional technology, especially of sequential mastery learning, has led to criterion-referenced testing of this kind. It is also employed in assessing student achievement for the formative evaluation of curricula. In both instances, its function is essentially diagnostic. On the other hand, it has been argued that total mastery does not exist and hence that criterion measures of unquestioned validity are not available. Moreover, the effects of teaching for mastery will be to limit the goals of learning to stated specifics with emphasis on the means of instruction and comprehension and with insufficient attention to application. The issue of generality versus specificity in learning is crucial to the conception, design and evaluation of any curriculum. It is by no means certain that all the advantages lie with specificity. While tests of specific achievements are usually developed by specialists, biology teachers are more concerned with tests across a range of attributes related to the subject. They acknowledge that learning in biology is necessarily incomplete. These opposing views are worthy of discussion.

The application of grading

It is possible to quote many public examinations in which certain predetermined grading levels are applied to defined scores, indeed, fixed pass-fail levels of, say, 40 or 50 per cent marks are of common occurence. Without adjustment, this would assume the existence of a valid criterion-referenced test in which questions of comparable difficulty are produced each year. Another examination procedure is to include certain fixed proportions of students in each grade, often related to a normal frequency distribution. Such systems are recommended in Australia, the United Kingdom and in countries which follow their pattern of examining. Thus grading acquires the attributes of a norm-references test in which the main concern is not with how much the student knows but with how he stands in relation to other students. Provided that the spread of marks allows for good discrimination, such examinations ensure a convenient method of selection. They tend, however, to obscure still further any notions of the criteria on which selection is made. Such criteria are needed both by potential users of the examination results as predictors of performance in higher levels of education or employment and by teachers interested in monitoring the progress of students by internal tests. Thus a key problem remains: how can test results best be transposed into grades? In Poland, Niemierko has proposed multi-level tests containing questions related to the essential content of the syllabus and to average and above-average knowledge of the subject matter. These could be used to find the lower limiting points of a four-grade rating scale quoted as insufficient, satisfactory, good and very good. A moderation of the predetermined proportions of students at each grade is carried out by the Joint Matriculation Board in England by scrutiny of all examination scripts at each grade limit in a band of 5 per cent for final adjustment of the grades. This helps in part to overcome the problem of reliability and criteria in traditional essay-type biology examinations but has little relevance to the objective testing which is being increasingly used.

Cumulative assessment

This can be advocated in situations where the need for rigorous selection is diminished in conditions of open access to further levels of education. With a diminution in competition, the notion of failure need not be included and the functions of diagnosis and student guidance can be developed. This can lead to a desirable flexibility in variation of the rate of progress and in the reinforcement of learning. The process of assessment itself can also be adjusted fairly readily in an internal situation. Cumulative assessment can take into account many aspects of cognitive, psychomotor and affective achievements. It is especially valuable for assessing practical work in biology and for gathering evidence on attitudes from observations of student behaviour.

While school-based tests may be included in the range of techniques available for cumulative assessment, the limited information from them can be supplemented by other means. Certain main issues, however, arise in the use of internal assessment. These become especially important when continuous assessment forms part of a credit system or is used as a component of a public examination.

Any form of cumulative assessment of achievement inevitably influences the relationships between teachers and students. The student who requires assistance in a learning situation may be reluctant to expose his weakness to the teacher and the teacher has to fulfil the dual role of teaching and testing.

Assessment of attitudes towards biology are part of the continual interchange between teacher and student during the process of education. However, the identification and measurement of specific attitudes is technically difficult and their inclusion in a cumulative assessment involving grading is of doubtful value. The impartiality and skill of biology teachers in making such assessments is particularly crucial, especially in countries where strong tribal or racial divisions exist and where a large proportion of the teachers are poorly qualified or have limited experience.

In cognitive and psychomotor skills it is possible to provide teachers with much guidance in assessment procedures by means of workshops and printed instructions. This is a valuable development for improving reliability and validity of assessments by teachers. This trend is seen in countries with traditionally unstructured forms of cumulative assessment and also in countries which are moving away from external written examinations towards assessment by teachers. Thus both systems are tending to converge on a common position.

Where printed material is provided for independent learning by students, it is possible to incorporates self-evaluation or procedures in the text. This can be used for self-evaluation or reinforcement. It is particularly useful for students who undertake a correspondence course. A well designed example of this is seen in the New Zealand course in biology for students at the pre-university level. The publications for the courses of the Open University in the United Kingdom provide the student with explicit objectives on the test exercises which can be checked against provided answers and discussed with tutors.

Self-assessment of a more informal kind is also being used in some countries. By discussing his own estimate of his achievement with the teacher, the student is helped in the process of self-evaluation and improvement and can make a contribution to cumulative assessment.

The nature of the biology curriculum

The style of the curriculum

Traditional public examination syllabuses in biology tend to stress factual content. Their laconic expression is related to examination expectations which become well known from experience. Such syllabuses are essentially declarations of intent with regard to examining and the actual curriculum is devised by the teachers.

New biology curricula are usually expressed in extensive printed publications in which details of aims, objectives, content and pedagogy may be made explicit. Related test material may also be provided for formative evaluation by teachers. (See the chapter on: 'Curriculum evaluation and dissemination'.) Such testing tends to be related to mastery learning by using criteria closely related to the design of the curriculum. Two main problems of assessment usually emerge. In the course of time, over-familiarity with standard tests reduces their validity. The production of a printed curriculum in detail, besides having a restrictive effect on teaching, may reduce the scope of testing. This latter problem becomes particularly acute if there is excessive dependence on the factual content of the curriculum for teaching and for testing. The range of test material can be extended if more attention is paid to the biological concepts and principles to be assessed and to applications and problems which involve their use.

A trend towards individualized student programmes in which students progress at their own rate, working at tasks which interest them has appeared in the United States and Canada. This represents an extreme form of student-centred education and offers special problems in assessment. Teachers may have to assess students in different achievements. Even when they study the same things they may learn at different rates and assessments will have to occur at different times. The guidance in assessment standards which is provided by comparisons between students is reduced. The main issues which appear are concerned with the role of assessment in such a situation and a consideration of the appropriate techniques of assessment. Some answers to these issues are indicated by Sweat in relations to an individualized course in college biology which she developed in the United States. Student-instructor interaction, oral questioning, extra credit options, self-evaluation and a comprehensive final examination which is discussed by student groups and related to student contracts are suggested (see bibliography).

External influence on curriculum content

New developments in biological science tend to affect the area of study at student level. For example, student programmes have taken some account of the modern findings in ecology, physiology, biochemistry, genetics and molecular biology. The extent to which these can be taught is related to the state of learning and level of concept development which can be expected in students. However essential the professional biologist may consider certain principles to be, such educational considerations cannot be ignored. The level of difficulty of tests must remain related to the level of concept development. New concepts in new areas of biology will require particularly careful testing.

There is evidence from essay-type answers that the inclusion of complex and difficult material such as metabolic pathways and molecular biology has led to excessive rote learning. On the other hand, where biological research illustrates science processes, student achievement in problem solving can be stimulated, for example in simple aspects of population ecology and the design of experiments. Testing of genetics or population genetics tends to produce an all-or-nothing result.

The part played by biology in integrated school curricula is likely to increase. Biology has much to offer in relation to social studies, psychology, political science, geography and economics. Within biology itself there is an increasing emphasis on areas of human interest such as population studies, conservation and problems of pollution and drugs. Both trends are likely to attract an increasing range of students whose primary interest is less in science discipline and more in matters of human concern. Attitudes and value systems are inevitably involved. Many of the issues are of a controversial nature which offer new challenges of the neutrality of the teacher. The obligatory nature of assessments accentuates this problem.

Techniques of testing which provide sufficient validity for the assessment of such studies must lie in the direction of adequately expressed communication. Assessment of process, especially in the use of evidence, becomes more important than assessment of results or part-

icular conclusions. Cumulative assessment of oral or written work and of exercises which involve special studies or surveys are not only appropriate but also more acceptable to students of this type. In written examinations, questions requiring essay-type answers allow the development of cohesive arguments which can be marked by impression by more than one examiner and thus reduce personal bias on debatable issues.

The effect of teaching approaches on assessment objectives

Many biology syllabuses embrace a number of interacting concepts from which it is difficult to discern a logical sequence of objectives and this is reflected in the tests derived from them. It is relatively easy to assess phases of biology which are readily structured such as the recall of specific facts or straightforward practical skills such as the use of the microscope or the identification of biological material. These, however, are trivial compared with the main educational needs of students. The scope of biology as a subject for study is so great that unless some main pattern is used in the design of a curriculum any scheme of objectives for assessment is likely to be unrepresentative. Styles of biology curricula vary from those which are mainly informational in their aims, teaching the subject in breadth, to curricula which are formational and use biology to illustrate the various aspects of science activities. Both of these styles may be combined in various proportions.

The biology curriculum designed for the middle secondary level in India exemplifies the informational approach in which biology is taught in relation to the social needs of agriculture, human nutrition, health and medicine. Four main objectives are stated.

- Familiarity with common and important plants and animals in their environment.
- Understanding of the basic structure and life processes of plants, animals and of man.
- Understanding of the main trends in the evolution of organisms, the concept of adaptation, the need for correct management of plant and animal resources.
- Understanding of a general relationship between man, and the plant and animal world.

For such a syllabus, the objectives of assessment are mostly related to content and might be expressed in three main categories:

- knowledge of biological facts and principles;
- application of biological principles;
- understanding the role of biological science in everyday life.

The breadth of biological study is more fully systematized in the Biological sciences curriculum study (BSCS) in the United States at the upper secondary level. It has the following unifying themes:

- change of living things through time – evolution;
- diversity of type and unity of pattern in living things;
- the genetic continuity of life;
- the complementarity of organisms and environments;
- the biological roots of behaviour;
- the complementarity of structure and function;
- regulation of homeostasis;
- science as inquiry;
- the history of biological conceptions.

The first seven of these are related to substantive course content. The last two categories, however, relate more specifically to genuine understanding of the seven themes and to the range of student behaviours when biology is taught by the inquiry method. Inquiry objectives may be categorized into the analytical mode, in which student understanding of research processes is assessed, and the contributory mode in which skills in design of experiments, recognition and formulation of biological problems and hypotheses are used. The most explicitly detailed statements of inquiry objectives are closely related to the writing of specific objective test items, thus

improving the precision of assessments. In countries where high levels of item-writing skills are available, this type of test development may be desirable. In many countries, however, a detailed analysis of science process skills related to education in biology is of more value for informing teachers of the detailed implications of the skills which are then tested in a few broad clusters of objectives. For example, in Thailand, a teachers' guide on assessment of students studying the new biology curriculum at upper secondary level (1975) offers the following detailed list of test objectives.

Knowledge

of biological facts, terms and principles;
of procedures in biology;
of mathematics, physics and chemistry essential for biology;
of criteria for ordering and classifying;
of historical developments in biology.

Comprehension

explanation, translation and interpretation;
calculation;
applying biological knowledge in routine situations;
making generalizations.

Processes of scientific inquiry

specifying a question in a problem as a hypothesis to be tested by an experiment;
designing an experiment to test a hypothesis;
interpreting observations and data in the form of conclusions;
expressing trends from data;
making predictions from data;
evaluating a hypothesis from data or from knowledge.

Application

using knowledge of biology to solve problems in new situations;
applying biological principles to social and technological situations.

Tests are constructed using the four main headings only as the assessment objectives.

The development of assessment objectives from the main aims of the curriculum in the Nuffield Advanced Level biology course was seen as the important device in securing a proper implementation of the curriculum through the prescriptive effect of a public examination. This effect continues by means of the design of questions and the feedback to schools through examiners' reports each year. This examination employs a variety of assessment techniques, each of which is considered appropriate to certain student abilities. The table indicates the development of specific assessment procedures from the general statement of aims of the curriculum.

Nuffield Advanced Biology Curriculum		
Aims of the curriculum	Assessment objectives	Assessment techniques
Acquiring a knowledge of living things and an understanding of the techniques used to study them.	Recall of biological facts and principles.	Objective test, essays, assessment of practical work.
Making observations and asking relevant questions about them.	Recording and handling results.	Assessment of practical work and projects.
Analyzing biological date and synthesizing it into conclusions and principles.	Handling data, constructing hypotheses.	Structured problems, comprehension of a printed passage, assessment of practical work and projects.
Handling quantitative information and assessing significance.	Handling data, translation, interpretation, computation.	Structured problems, assessment of practical work and projects.
Critical judgement of hypothetical statements in the light of their origin and application.	Assessing hypotheses, designing experiments.	Objective test, essays, assessment of practical work.
Making use of acquired knowledge for identifying and investigating	Devising, carrying out and presenting an individual project.	Assessment of projects by using operational divisions.
Evaluating the implications of biological knowledge for human society.	Expression of evaluative judgements supported by criteria.	Essays, comprehension of a printed passage.
Communicating biological knowledge both coherently and with relevance.	Coherent and logical communication.	Essays, reports on projects.

The allocation of marks for the various assessment techniques in this examination are as follows:

Objective test	20%
Essays	20%
Structured problems	25%
Comprehension of a printed passage	10%
Assessment of practical work in class	15%
Assessment of student projects	10%

Both in the use of formative testing and in the development of new styles of terminal examination some allowance must be made for a maturation factor which operates both in teachers and students. New skills have to be acquired and internalized and early tests may not be entirely valid.

A further problem lies in the establishment of appropriate grading standards in new forms of assessment which are often introduced with new curricula. In some instances there is a period of overlap of old and new assessment procedures and the problem of equivalent becomes acute.

The uses of different techniques of assessment

A range of assessment techniques is available which, if effectively utilized, can meet, at least in part, some of the criticisms which arise when a single test is used to assess a complex of achievements. The uses, disadvantages and advantages of the main techniques are briefly reviewed.

Oral tests

These allow students to demonstrate knowledge and understanding and also their ability to respond to 'critical incidents' such as the presentation of biological material which requires identification or which poses problems. The examiner has the opportunity to ask supplementary questions. Attributes of personality can influence examining.

Disadvantages
- Standardization is difficult
- Personality bias may influence cognitive areas.
- Only a limited sampling of a course is possible.
- It is costly in time.

Advantages
- It is a flexible form of assessment.
- Simultaneous assessment by more than one examiner is possible.
- It can be used to elucidate other forms of assessment.

Oral examining has been a tradition in many European and Asian countries, questions sometimes being selected on a random basis to avoid personal bias. A particular use of oral testing is advocated by Tamir (1972) for biology assessments. Students who have made studies in depth of certain organisms or biological situations are given opportunities to present their findings and to answer critical questions. The results are used to supplement other techniques of assessment.

In some self-instructional biology courses for undergraduates in the United States, quiz sessions are used in which groups of about 12 students are subjected to oral tests. These are then used as a qualification to take further written test. Such a procedure can help to mitigate the isolation of students engaged in self-instructional procedures. The questions are closely related to the objectives of each module of instruction. Before answering a question, each student selects a particular objective, to which the question refers. Such assessments must be made frequently and inevitably restrain interaction between students. There is the further problem of using a single tutor for the simultaneous assessment of the individuals of a group.

Assessment by written tests

The relative merits of assessment by objective tests and essays have been widely discussed. The original trend towards objective testing continues, especially where course assessment for a system of credits is employed. There is also an increasing interest in diagnostic testing using objective techniques. The problem of examining on an increasingly large scale have caused administrators to turn to objective testing. However certain problems emerge.

The supply of expert item writers is limited. There is a continual need to identify and train such persons. The employment of teachers experienced in the relevant curricula for this purpose is most likely to produce valid material. When tests are to be used for public examinations, problems of pre-testing and security arise. These are more readily solved when the test is organized on a large scale.

In countries which have objective testing extensively, there is some evidence of a trend towards the use of short essays as a complementary form of assessment. The Advanced Placement examination of the United States gives equal weight to both techniques (Kastrinos, 1974). Essays provide special opportunities for assessment of the skills of coherent expression, synthesis and evaluation. Provided that the topics are well defined, such short essay questions can avoid the traditional disadvantages of several interpretations of a question by students and excessively arduous marking tasks. Essay questions have long been used to provide evidence of study in depth. A student may well have made such studies by selecting certain parts from a wide syllabus. The relevant examination has offered a wide choice of questions. This approach has also been used in examining biology syllabuses overloaded with factual content. A free choice of four questions out of nine gives 16000 possible combinations of questions. Many examinations have offered a wider choice than this. Thus, in effect, a multiplicity of examinations is being assessed and placed in a single rank order. Moreover, it is hardly possible for all the questions to be of equivalent difficulty or to test the same skills. Such considerations have been influencing the trend towards examinations with compulsory sections, each with certain main objectives and different techniques.

Accompanying this trend, there is an increasing use of course assessments of studies in depth.

Structured questions which require extremely short answers for each part have become increasingly common in biology examinations at the secondary level. The subdivision of the material provides an element of objectivity which makes marking reliable and the student is left in little doubt as to what is required. This question type can make use of diagrams and biological data and can provide opportunities for testing specific science process skills. By posing biological situations it can be used to test cognitive skills related to practical work very effectively. In the Nuffield Advanced level biology examination a section of such questions is used as a moderating instrument for the internal assessment of practical work. Problem-type questions in biology tend to have an all or nothing effect. If they are used in a compulsory section of an examination it is better to provide a number of short problems rather than a few large ones in order to obtain a truer assessment of students.

The use of printed passages to test the comprehension of biological literature by students is relatively uncommon. Comprehension questions need to be short and numerous and can be arranged in accordance with a progression of cognitive levels. Students must depend on the passage to answer the questions, but they may also be required to relate material in the passage to their biological knowledge (Lister, 1969). This ability to acquire new information from reading and to relate it to previously acquired concepts is fundamental to a continued education in biology.

Open-book examinations are reported in some tertiary level assessments in biology. Access to literature during the testing of problem solving achievements is most relevant to specialized studies, especially at tertiary level. The problems used tend to be open-ended and the time allotted is flexible. Reliance upon recalled knowledge is minimal.

Assessment of practical laboratory work

In biology courses which include practical exercises as an integral component, some account is usually taken of the assessment of practical skills. Three areas of skills can be assessed.

1. Manual skills, such as microtechniques, dissection, and the handling of apparatus. These require each student to be watched.

2. Complete exercises involving a range of psychomotor skills such as understanding instructions and carrying them out, using the results of exercises for recording and further cognitive skills. These are often tested in practical examinations or in teacher assessments.

3. Outcomes of practical work such as drawings, written records, dissections, micro-

preparations, handling of results by computation, inferences from observation, assessment of hypothesis. These can be assessed after the practical work is finished: They are the most conveniently assessed skills in formal practical examinations. Only at a high level and with fairly wide resources is it possible to test the design of an experiment and its implementation in a formal examination.

Practical examinations. The special virtues of impartiality and uniformity usually claimed for examinations are offset by the special restrictions imposed on the nature of the practical work in biology which can be assessed. There is a restriction of time which limits the choice of exercises. Many biological experiments are of long duration and cannot be tested. Biological material is variable and provides only a limited range of experiments from which definitive results can be expected. Many biological investigations are open-ended and assessment is more properly carried out on the process than on the end product. The questions in a practical examination are necessarily limited in number and range, providing a very limited sample of students' skills. A small error, such as the severance of a blood vessel in dissection, or failure of a potometer can be crucial to results. In such tests, students show more signs of stress than in any form of assessment. In public examinations, the increase in numbers of candidates and in costs has led to severe administrative problems.

A detailed list of the objectives of a practical test which forms part of a public examination is a powerful instrument for influencing the teaching of biology. The statement by the Joint Matriculation Board in the United Kingdom on Advanced Biology comprises the following four main headings.

1. To investigate and compare the macroscopic structure of organisms.
2. To investigate, compare and record by means of diagrams and drawings the microscopic structure of organisms.
3. To conduct (or observe demonstrations of) experiments, with description of procedure, presentation of data graphically or otherwise, discussion of data and drawing of conclusions.
4. To recognize the major plant or animal groups to which specimens belong.

Further details are given within each of these sections which are tested in a three-hour examination.

A different approach to the statement of objectives is shown by the East African Examinations Council for the Advanced Certificate in Biology. The expected practical activities are specified in each section of the syllabus in relation to each area of study. A practical test of one and a half hours is based on these.

Cumulative assessment of practical work. Provided that certain problems can be solved, the case for assessment of practical work by teachers rather than by a terminal examination can be supported on both educational and administrative grounds. Assessment in class enables a range of skills to be sampled over a period of time. Biological exercises which cannot be tested in limited, formal examinations can be taken into account. Accountability, whether in a system of internal credits or as a component of a public examination makes it essential to specify the areas of assessment.

There are two opposing views on the extent to which such specifications should be used to guide teachers. The Nuffield Advanced Level Biology assessment is kept as simple as possible in order to make the teachers' task as light as possible. The full descriptions of the practical exercises in a printed text make this feasible. Three operational divisions are used.

A. Procedure. B. Recording. C. Handling of results. Some further details for the interpretation of these divisions are also given.

On the other hand, the Joint Matriculation Board requires the following five abilities to be

assessed.

A. Possession of appropriate manipulative skills.
B. Carrying out observational investigations.
C. Carrying out experiments or procedures in accordance with instructions.
D. Handling experimental data.
E. Planning investigations and experiments.

Further details are given, with a grading system for each of these abilities. In addition there is a comprehensive pamphlet of suggestions for practical exercises and their assessment.

During the trials of the Nuffield Advanced Biology curriculum, three alternative methods of assessment of practical work were investigated (Kelly and Lister, 1969). These were assessment by means of structured tests with closely defined objectives, assessment of current class exercises, and global assessment over a period of time. The global assessment procedures were found to be comparable in accuracy to the structured tests and more convenient to administer. The current procedures for this course were developed as a result of this investigation.

The special problems of grading practical skills lie in their diversity. If a large number of categories are separately assessed, there is a regression towards the mean when they are combined for a single grade. Moreover, opportunities for obtaining a profile of abilities are lost. Such lack of discrimination on both counts is evident in practical examinations. This reduces their weighting as a component of the whole assessment of student achievement in biology.

The establishment of comparability of standards of assessment between different schools poses special problems in relation to practical work. Moderation by an external agency can be applied to recorded outcomes of such work. External reference tests which test skills related to the results of practical exercises are both expeditious and reliable as a form of statistical moderation of actual psychomotor skills remains a problem. Assessment of these involves actual observation of students in action, a procedure which is difficult for the teacher and even less practicable for a visiting moderator.

Assessment of individual practical projects. The inclusion of these in assessments of biology courses offers fewer problems in a system of complete internal assessment than in public examinations. In the latter case, the problems of comparability and moderation become acute. A solution to these problems was proposed by the Nuffield Advanced Biology curriculum development team (Eggleston and Kelly, 1971). In this curriculum, the wide variety of projects is now assessed under the following operational divisions.

1. Statement of the problem.
2. Investigation of background knowledge.
3. Planning the procedure.
4. Inferences from practical work.
5. Relating inferences to background knowledge. Suggestions for further investigation.

The definition of a project in this curriculum is fully discussed in an explanatory booklet. Each division is graded on a five point scale and the projects are moderated by a team of external assessors who scrutinize the written reports of students.

PROBLEMS OF CHANGE

The development of a biology curriculum must take into account not only the constant factors of biological science but also the influence of regional variables. These include the social needs of people, cultural attitudes to life and the nature of local ecosystems. As curricula move towards greater relevance such variables become more prominent. This is especially true at lower secondary level and in respect of those for whom the study of biology is part of a pattern of general

education. For upper secondary and tertiary levels, the constants of biological science become more prominent objectives, not only in relation to the universality of formal thinking but also as part of a wider currency of qualification in biology.

A very full commitment to local relevance has been developed for the new general science curriculum at the lower secondary level in Sri Lanka. This is related to pre-vocational studies based on local crafts and industries. About 75 per cent of such studies are biological, such as fishing, crop growing and handling agricultural products. This a development is intended to counteract the alienation of students from local employment opportunities, an alienation which is often associated with academic studies. The National Certificate of General Education taken after four years consists of:

Paper I. 45 objective items on recall, comprehension and application.
Paper II. A. Structured questions related to practical skills.
B. Free response questions to test critical abilities and conceptual levels, with some evidence of attitudes.

Local assessment of the practical skills is to be introduced gradually. Eventually it is hoped to give equal mark allocations to internal and external assessment.

Trends to replace external examinations by internal assessment in schools are apparent in Australia, New Zealand, Canada, and several European countries. In India, the Examination Reforms Committee has recommended a system of autonomous schools similar to the accredited schools of the United States. In Thailand, internal assessment is proposed as a logical concomitant of the change to a system of semesters.

Producing valid assessments on the whole range of skills in a curriculum represents a severe challenge to teachers. A transformation of the functions of the central examining authority could provide support by the following developments:

- organizing pre-service and in-service training in the complex skills of test writing;
- providing models of test design, together with teachers' guides;
- providing a bank of items on which teachers could draw for the construction of tests;
- organizing schools in groups for mutual support in testing.

In the United States, much use is made of commercially produced tests available from a number of agencies. In several countries, books of test items are published, many of them, however, of poor quality.

Grobman (1966) has indicated that teacher-made tests generally highlight isolated knowledge of some sort. Firstly, because of a lack of expertise for testing higher-level skills and, secondly, because the items tend to refer to previous learning situations and therefore regress towards recalled knowledge.

INTERNATIONAL CO-OPERATION IN ASSESSMENT OF STUDENT ACHIEVEMENT

Exchanges between countries

Countries at equivalent levels of development in culture and biology education can usefully exchange ideas on assessment techniques. The adoption of a new technique is facilitated when its successful application in a corresponding situation can be appraised. A previous knowledge of the problems of implementation of techniques can reduce the period of time required for trials and adjustment in developing new forms of assessment. Such co-operation has been notable in the development of objective testing where the experience of the United States has been drawn on by many countries. In the field of cumulative assessment of practical work, the developments of the Nuffield Biology Project in the United Kingdom have been utilized in other countries. Australian experience in diagnostic assessment techniques is likely to be of great value in the development of formative tests. Exchanges of experience of assessments at the local

level and of the assessment of student projects are now possible between developing countries and are more likely to encourage their application than the direct provision of techniques from more developed countries. Some sharing of item banks is already taking place between developing countries. This could be extended as part of the co-operative activities in biology education within a region. A range of materials, especially documents offering specific guidance, is available from a number of projects in developing countries. These could be selected on the basis of their relevance and distributed more widely.

Visits

Visits of specialists in assessment already take place in various curriculum development projects. Their functions are concerned with policy, aims, objectives and techniques. Their initial activities involve the relation of assessment to the curriculum and the ultimate outcome of their work is the production of a viable team of examiners. At all stages, their work is related to the evaluative activities of curriculum development. The critical stages of implementation of a new curriculum on a wide scale require the special attention of evaluation experts, including assessment specialists.

Short-term visits of key personnel from developing countries, especially those concerned with administrative organization, to corresponding institutions in other countries is a useful and rapidly assimilated form of co-operation.

On the longer term, studies and researches by students at the higher-degree level in universities can assist countries to produce their own assessment specialist.

Studies in assessment

Two types of research are indicated.

System maintenance research. This is concerned with the improvement of existing assessment systems. On the international scale, some studies in equivalence of assessment between countries have been undertaken. A continuation of this trend would enable countries to compare their respective views and progress at various levels of education. Such comparisons would provide further stimulus for the improvement of validity, reliability, profiling, diagnosis and prediction by the establishment of good criteria for assessments in biology education. By such controlled change in assessment, biology education itself can be improved while ensuring continuity within the schools.

Evaluation research. Investigations of the more fundamental issues of assessment have led to numerous small-scale researches. However, much remains to be done in areas which require international co-operation. Investigations of the objectives which could be appropriate at various levels of cultural development and the forms of assessment which are related to them require development. The effects of assessment on the transition between the various levels of education where there are conditions of restricted access need urgent study. Conversely, studies of the economic and social context within which assessments are made would be a useful step in improving their relevance and credibility.

SUMMARY AND RECOMMENDATIONS

1. Assessment activities should be directly developed from statements of the educational objectives of the biology curriculum. Assessment of students at lower levels of education should be concerned with their level of concept development. At higher levels of education some approach to absolute standards of competence in biological science is to be expected.

2. Effective teaching requires continuous diagnosis of the state of achievement of students. The employment of diagnostic tests as an integral part of biology education is a valuable aid to the process. Teachers may be supported in such testing by the provision of items from a central bank or by complete tests produced by experts.
3. The testing of objectives in biology should not be obscured by excessive requirements of verbal skills (such as comprehension and expression) in the lower levels of education or in cultures in which opportunities for such skills are limited. At higher levels of education, verbal skills should be tested as an essential part of science education.

   Written tests of student achievement are most likely to reflect the objectives of a course when they are constructed on a two-dimensional matrix in which one dimension is concerned with the content of the biology curriculum and the other with the behavioural skills which students employ in their answers. These skills should include the recall of knowledge and comprehension of biological principles and also those related to processes of science such as the application of principles, the handling of data, construction and testing of hypotheses and problem solving.

   A representative assessment of aims of the curriculum is more likely to be obtained by employing a variety of assessment techniques rather than a single style of testing. Students should be required to respond to a range of question types, preferably used in separate sections of an examination. These might consist of objective items, structured questions and essays. In addition to these, assessment of specific activities during the course of study could be used.

   The reliability of written examinations as consistent measuring devices for student achievement could be improved by reducing the extent to which students are offered a free choice of questions. The variations in levels of difficulty and in the skills which are tested in different questions tend to make any selection of them a unique test for each student. Conversely a test of compulsory questions offers a consistent measurement of all the students who are being assessed.
4. As practical experience of biological material, phenomena and experiments forms an important part of biological education, assessment of student activities in these areas should be made. Cumulative assessment of student achievement provides opportunities for diagnosis of the skills of observation, manipulation and recording as well as for elucidation by oral questioning. Formal examinations of practical work are less concerned with process as they tend to be confined to assessment of the outcomes of practical skills. Moreover, they preclude the assessment of long-term biological experiments and also produce problems in assessing experimental results from variable biological material.
5. The complete educational effects of a curriculum will include the development of attributes in a biology course might include those which are essential to science such as curiosity, persistence, willingness to think critically and favourable attitudes towards the study of biology. While the inclusion of such attributes in schemes of cumulative assessment is questionable, the diagnosis of these is a valuable part of the communication between teacher and student. Further research is needed on the effect of attributes on student achievement.
6. Opportunities for students to work in groups occur in various forms of practical work, field work and projects. Assessment of such groups as a whole can increase enthusiasm and attitudes of social responsibility. If individual assessments are required from groups the work of each student must be identified and some of the advantages of group assessment are lost.
7. Accepting that achievement of some objectives can be assessed most appropriately by teachers, it is recommended that in any external examination system, teacher assessment should be included as some part of the final assessment of the student. At the same time the equivalence of standards of assessment between schools and institutions should be

included as some part of the final assessment of the student. At the same time the equivalence of standards of assessment between schools and institutions should be maintained by some form of moderation.

8. Pre-service courses for teachers should include training in the various techniques of assessment with some indication of their use in relation to particular objectives. Teachers at all levels and other persons concerned with examination procedures should be encouraged to attend in-service courses for similar training, for information on new techniques and for the purpose of making their own contributions to changes in styles of assessment.
9. Co-operation between teachers in test development and other assessment techniques is desirable. Sharing of assessment material on a local basis is a useful form of reinforcement of such activities in schools.

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Procedures for developing instructional objectives models and classifying them. Methods for ensuring quality control in testing them are outlined.

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Kuhn, D. J. Behavioural objectives. *Science Education,* 54, June 1970, p. 123-126.

A strategy for developing objectives by first defining the terminal behaviours which enable the pattern of testing to be decided. A biological example is used.

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A review of a range of examination techniques and their application to different objectives.

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A survey of purposes, patterns and methods of selection with the problems and proposals for reform outlined.

Nakayama, K. *Evaluation: its meaning in new biology teaching and training of teachers.* Asian Association for Biology Education, 1970.

A report on the results of test trials and opinion surveys on assessment objectives and techniques. The problems of teacher competence in testing the disjunction between student experience and tests are discussed.

Orejas, B. M. Resultados de la encuesta sobre la ensenanza de las ciencias biologicas. In: *Segunda Conferencia Interamericana sobre la Ensenanza de la Biologia.* Washington, 1973.

A paper analyzing trends in the styles of assessment in 19 American countries presented at the conference at Asuncion sponsored by the Organization of American States.

Plewes, J. A. Evaluation of attitudes and interests in a science course. *SCEA Bulletin,* 9, Spring 1975, p. 8-10. The application and results of a test on non-cognitive attributes on selected and non-selected groups of children at the middle secondary level.

Saunders, A. *European Curriculum Studies no. 3; Biology.* Council for Cultural Co-operation. Strasbourg, 1972.

The status of biology teaching is reviewed. Examinations are related to teaching methods and the varying emphases in curricula. Examples of examination questions from a selection of European countries are included.

Selmes, C. (ed.). *New movements in the study and teaching of biology.* London, Temple Smith, 1974.

Contributions include a chapter on approaches to assessment in biology showing a spectrum of techniques with examples. The chapters on attitudes and the need for change are also relevant to trends in assessment.

Simpson, R. D. Evaluation of non-cognitive achievement in biology. *The American Biology Teacher,* 35, November 1973, p. 441-444.

Proposals for replacing intuitive evaluation of non-cognitives by use of objectives and a check list. The use of the Likent scale for obtaining a numerical score is outlined.

Sweat, J. An individualized course in college biology. *The American Biology Teacher,* March 1974, p. 156-160. The format, modules and content of the course are related to the special problems of assessment of individualized learning. The techniques of assessment used on the course are given.

Tamir, P. The practical mode. A distinct mode of performance in biology. *Journal of Biological Education*, 6, June 1972, p. 175-182.

Evidence is presented of three distinct modes of performance in biology: analytic, constructive and practical. A laboratory test for skills which cannot be measured in written tests is described.

Tamir, P. The role of oral examinations in biology. *The School Science Review*, 54, September 1972, p. 162-165.

The employment of oral examining in conjunction with other forms of assessment is advocated. Results of trials in which achievement in oral examining is compared with other measures, are given.

Thompson, J.; Slatzman, K.; Griffith G.; Joko, R.; Samples, R. Behavioural objectives. The paper tiger of accountability. *The American Biology Teacher*, May 1973, p. 119-120.

Various arguments against the use of behavioural objectives on students, especially in curricula of "self realization".

Developments in the training and retraining of school biology teachers

INTRODUCTION – BIOLOGY TEACHERS AS EDUCATORS

The powerful and thought-provoking Unesco publication, *Learning to Be*, makes the following statements (78[1] p. 216-17).

- One of the essential tasks for educators at present is to change the mentalities and qualifications inherent in all professions; thus they should be the first to be ready to rethink and change the criteria and basic situation of the teaching profession, in which the job of educ-

1. Numbers refer to the bibliography, page 184.

ating and stimulating students is steadily superseding that of simply giving instruction.

- 'Present-day divisions between formal and informal, school and out-of-school, child and adult education are steadily fading. Furthermore, teachers trained today will still be exercising their profession after the year 2000. Their training should be designed with these two facts in mind.
- 'Conditions in which teachers are trained should be profoundly changed so that, essentially, they become educators rather than specialists in transmitting pre-established curricula; the principle of a first, accelerated training stage, followed by in-service training cycles, should be adopted'.

What characteristics, then, make the biology teacher an educator 'rather than a specialist in transmitting pre-established curricula'? Most training programmes developed in the past five years have tended to focus on the development of professional competence rather than on merely training in the understanding of biological concepts or in academic pedagogy (284). Competency-based teacher education has become a theme for the second half of the present decade. Authors such as Houston and Howsam (122) have discussed the characteristics of competency-based instruction. Such instruction involves clearly specified learning objectives in behavioural terms; specification of one or more means for determining the objectives; specification of the methods of assessing achievement of the objectives; public sharing of the objectives, means of assessment, criteria and alternative activities; and assessment of the learning in terms of competency criteria. Competency-based programmes usually imply mastery learning and they place on the learner the responsibility for meeting the criteria set down for the course (122: p. 5-6).

There are many examples of programmes which place some stress on competency as defined above. Mention may be made of the Science Teacher Education Programme (STEP) in the United Kingdom (110, 111, 264, 265), and of programmes in Australia (171), Canada (214), Nigeria (291, 308), the Philippines (117), Thailand (162) and the United States (6, 7, 24, 52, 95, 142, 161). General considerations of competency and of relevant models for teacher education have been reviewed in a recent Unesco report by Razik (235). Competency-based programmes, however, have little meaning unless placed in a broader context.

In 1968 Joyce, in a report issued by the United States Office of Education (137), proposed an overall model for teacher education. He suggested that training programmes should aim to fit teachers for four basic professional roles. These are as follows.

The scholar - the teacher should have a sound general education; be an expert in his special field; and have a good understanding of children and of teaching.

The interactive teacher - with a flexible personality sensitive to the needs of learners.

The teacher innovator - a teacher committed to the inquiry approach, constantly willing to test new ideas.

The institution builder - a teacher as a member of a team understanding the processes involved in developing organizational system and the process of selecting goals.

Haysom and Sutton (110), in developing a rationale for the Science Teacher Education Project in the United Kingdom (111, 248, 264, 265), closely parallel the ideas of Joyce, giving examples of the desirable characteristics of teachers as follows:

- The capacity to be an effective manager of learning - emphasizing the importance of the curriculum.
- The capacity to create and maintain productive relationships with pupils - stressing personal interaction.
- The capacity to adopt roles suitable for teaching - stressing role change.

The attributes of good teaching have been the subject of much research and this has been well reviewed by authors such as Biddle and Ellena in their monograph Contemporary Research on Teacher Effectiveness (20) and more recently by Morrison and McIntyre (191) and Smith (253). Sixten Marklund (178) points out, however, that the teacher operates at two levels, the micro-

level and the macro-level. The former refers to classroom behaviour and the latter to the teacher 'as a community functionary in a broader sense'. Marklund believes that it is in the combination of the micro and macro-level behaviour that 'we have a chance of developing new theories concerning teacher aptitude and teacher effectiveness'.

There are a number of useful statements about the desirable general attributes of a science teacher and of a biology teacher in particular. One such statement issued by the National Science Teachers Association (NSTA) of the United States (202) is in the form of a 'self inventory' or checklist. The NSTA list suggests that a professional science teacher: is well educated in science and the liberal arts; possesses a functional philosophy of education and the technical skills of teaching: continues to grow in knowledge and skill throughout his career; insists on a sound educational environment in which to work; maintains his professional status; contributes to the improvement of science teaching; and takes a vital interest in the quality of future science teachers. At the University of Maryland a useful checklist of seventy-five desirable professional attributes has recently been developed by Melton Golman (95). Golman claims that this list also provides a tool for in-service teachers to 'self-assess their basic science teaching competencies'. The list is grouped under the following headings: instructional foundations; instructional techniques; curriculum development; (knowledge of) professional organizations; instructional media; material preparation; and emergency procedures.

In 1973, the National Foundation for Educational Research in the United Kingdom published a handbook of *The Objectives of Teacher Education*, developed by the Institute of Education of Leeds University (159). This list is in the tradition of competency-based teacher education as it provides parallel lists of the needs of pupils and the professional needs of the teachers. It thus implies an accountability in terms of the behaviour of pupils. The statement of pupil needs includes items such as 'to develop the ability to observe, measure and record' whereas the teacher may be expected to become skilled in professional matters such as 'devising schemes of work and lesson plans' (159: p. 26-27, 32-34, 44-46).

With respect to specific skills required of the teacher of biological science two recent studies are of considerable interest. Beisenherz and Probst (19), working with biology teachers in four widely separated cities of the United States in 1973, identified 35 biological techniques and skills that these teachers believed should be acquired by teacher trainees before they begin teaching secondary school biology. Techniques includes such skills as using microscopes, pithing frogs, measuring pH, using kymographs and applying streak-plate techniques in microbiology. In the United States, Addison Lee has examined the skills of the biology teacher on a broader basis and in his valuable monograph on the pre-service preparation of secondary-school biology teachers has included a comprehensive checklist of skills originally developed in 1966 by the Commission on Undergraduate Education in the Biological Sciences (CUEBS) (156). This checklist is in three parts. The first part lists nine skills relating to the philosophical basis of biology teaching; for example, to develop an awareness of the interaction between biology and society or an understanding of the ethical responsibilities of the biologist. The second part is concerned with personal competencies. Ten such competencies are listed, including the need to develop and strengthen self-confidence and to be skilled in determining materials, equipment and supplies needed and in the procedures for ordering. Part three concerns the pedagogy for prospective biology teachers. Twelve skills are listed under such headings as the philosophy and rationale of the biology programme, use of instructional media, classroom techniques, planning science facilities and evaluation techniques.

These and similar statements about the desirable characteristics of the biology teacher have evolved, in part, in response to changing emphases in school biology curricula. Schools now stress attainment of broad general educational objectives rather than those related only to the limited interests of the academic biologist. These objectives emphasise intellectual skills associated with inquiry learning (49, 50, 87, 138, 206, 262, 300) and stress issues of individual, social and national relevance such as health, personality development, agriculture, economic growth and attain-

ment of national goals. More established programme such as the Biological Sciences Curriculum Study (BSCS) in the United States (99), and the Nuffield Biology programmes in the United Kingdom (144) have influenced newer and even more broadly based programmes such as secondary school biology courses now offered in East Africa (187, 269, 286); Guyana (149); India (128, 183); Malawi (176); Malaysia (250); and the Philippines (117), to name just a few. Some biology courses have evolved into broader programmes of integrated science or environmental studies (233). Examples include the Australian Science Education Project (ASEP) (234); the socially oriented integrated science programme that began in 1973 in the mid-western state of Nigeria (90); the integrated science programme for secondary grades 1 to 3 and the general science programme for secondary grades 4 and 5 in Malaysia (250); the integrated science programme for ages 12 to 15 in Ireland sponsored by Trinity College, Dublin (225); and the West Indian Science Curriculum (295, 311).

These trends reflect the strong pressures on the curriculum maker to correlate courses more closely with the needs of society. In turn they have resulted in a rethinking of the roles of the biology teacher and of his desirable attributes. They have contributed to a reorganization of the objectives, patterns, content and processes of his pre-service and in-service training. As biology teaching becomes more relevant it also becomes relatively more popular compared with other sciences as shown in recent surveys by O'Donovan in the United Kingdom (213) and Fensham in Australia (90) and this, too, has implications for patterns of training and retraining.

In summary, the qualities and characteristics of biology teachers have changed from those needed for the organization and relaying of factual information about biology to more broadly defined professional competencies with a stress on problem solving and inquiry learning. The newly trained biology teacher must be flexible in the face of social change since he must now teach courses of direct relevance to the needs of individual and of society. He must be flexible, too, in coping with a rapid growth in the popularity of biology as a school subject in preference to the physical sciences. The trend in training, therefore, is towards competency-based programmes of teacher education.

PATTERNS OF PRE–SERVICE TRAINING FOR THE SECONDARY SCHOOL. CONSECUTIVE OR CONCURRENT TRAINING?

The James Report (62) on teacher education in the United Kingdom proposes three cycles in the development of a practising teacher. The first cycle is a two-year diploma of higher education stressing personal educational development. The second cycle is a two-year teacher training programme in which one year is spent in a training institution and another in a school. The second cycle 'should be specialized and functional by being directly related to the work likely to be undertaken by the prospective teacher at the beginning of his career' - a plea for a competency-based programme. Further professional growth, the training of the teacher for future developments and to cope with change, is the concern of the third cycle. In a planning paper prepared for the School of Education, Macquarie University in 1974, Harry Thompson (272) suggests that the skills of Joyce's 'innovator' and most skills associated with Joyce's 'institution builder' (137) are properly the province of the third cycle of development as defined by the James Report - that is the in-service phase.

The James Report is an attempt to answer the perennial problem of the teacher educator who 'has to produce a product in the present that must operate in the future'. Yet to cater for an uncertain future is likely to increase the traditional complaint of the trainee that much of his experiences are irrelevant to the realities of the classroom as he experiences them during the training. Frequently unable to cover adequately the needs of the future plus the present, the training institution is forced to offer only partial treatments of present and future considerations (272). The James Report offers a solution by restricting the field of pre-service education and by extending in-service experiences.

Another problem of concern is how best to maintain a balance between the content and structure of biology, on the one hand, and of training in pedagogy, on the other. Traditionally, in most European school systems and until recently in many developing countries, the method for training secondary school teachers has been by means of a conventional science degree with a biology major followed by an 'end-on', i.e. consecutive year of teacher education - the conventional B.Sc. Dip. Ed. approach. The main difficulty with this is usually the lack of integration of objectives at the various levels of the programme and the divergent philosophies of the scientist and of the educationalist. In the 'end-on' approach, development of most of the attributes and professional competencies listed in the first part of this chapter is unrealistically compressed into the last year of the four-year programme. Some end-on programmes, however, have tried to overcome this problem by maximizing the development of teaching skills. The Diploma in Science Education offered by Monash University, Victoria, Australia (81, 82, 101) is an example. This course is designed to capitalize on the particular science backgrounds of students. There are three components. Firstly, there is a core programme in science pedagogy undertaken by all students. The second element is a series of elective units or minicourses involving both skills and science content. These are laboratory-based and designed to provide skills in areas not covered by the earlier training. The third component is a week-long residential camp during which groups complete an assignment on a teaching unit. Another example of an up-dated approach to 'end-on' training is provided by the University of London Institute of Education (165, 292).

In France, where all biology teachers also teach geology, the training scheme for secondary school teachers *(lycées* and *colleges)* involves academic training of four or five years' duration within the universities and under their authority; this part of the training is of a rather high level and does not necessarily differ from that of those who are trained in biology and geology but do not want to be teachers. After these purely university studies, the future teachers take national examinations, the *Certificat d'aptitude au professorat de l'enseignement secondaire* (CAPES) after four years of study, and the *'Agregation'* after five years. Having passed one or the other of these examinations, the student teachers are given padegogical training lasting one year in regional centres (*Centres pédagogiques régionaux* or CPR which come under the authority of the Ministry's General Inspectorate *(Inspection générale)*: as a main activity, they attend what are essentially 'workshops in the classroom' with senior teachers - this involves a total of 27 weeks in the year. Such a scheme which has been applied since 1950 is now evolving, first by the creation in some universities of concurrent schemes of training, within the framework of which academic and pedagogical training co-exist; then by the creation of research and teaching units *(Unités d'enseignement et de recherche*, UER) devoted to education.

Another factor in the evolution is the development of pedagogical research within the National Institute of pedagogical research and documentation (*Institut national de la recherche et de la documentation pédagogiques'*, INRDP) and the establishment of pilot schools (121).

The alternative to the end-on (or consecutive) programme is the parallel or concurrent pattern. In the concurrent approach, the training in the discipline of biology is given in parallel to the training in pedagogy throughout most of the programme. In some concurrent programmes, the didatics (i.e. teaching methods of biology) are covered in a department of biological science and in others in a department of education. In a few cases, the staff is not differentiated and the content, didatics and pedagogy of biology are taught throughout the whole programme by the same staff. The most wide-spread pattern of 'concurrent' training is the Bachelor of Education programme (B.Ed.). In the United Kingdom, these degrees are four-year programmes offered by Colleges of Education. Three years of attendance at such colleges leads to the award of the Certificate of Education with Science and graduates are qualified to teach in primary schools and in the lower forms of the secondary school (30, 56, 61, 279). A survey completed in 1971 of Colleges of Education in the United Kingdom indicated that 98 of 161 colleges of education offered B.Ed. courses in biology and that in the majority (86 cases) the training of B.Ed. students was concurrent with that of Certificate students during the first three years (12). The joint

honours degree in science and education offered by Chelsea College, London (39) is an example of this type of programme. The concurrent B.Ed. programme offered by Worcester College of Education is also typical (312).

The B.Ed. approach is now well established in other parts of the world and has had varying success according to how well the concurrent elements of biology and pedagogy have been interrelated. In Cape Coast University, Ghana, the concurrent programme is developed in close association with the biology panel of the Ministry of Education (211). The student teachers are required, during their first year at university, to actually work through the biology syllabus in use in the schools including completing all practical assignments. Interesting concurrent programmes are also offered by the following institutions: the University of Melbourne in Australia (208), Nigerian universities (291, 308), Njala University College in Sierra Leone (38), University of Malawi (48), University of Port Elizabeth, South Africa (192), University of the South Pacific in Fiji (48), and the University of Zambia (243). Concurrent programmes in the United Kingdom and in certain countries of the British Commonwealth have been reviewed by Barnes (13), D'Aeth and Brown (56), Greswell (98), Hughes (for Pakistan) (124), Northfield (for Australia) (208) and Ghani (for Malaysia) (93, 290). Some interesting examples are also described in the report of the Commonwealth Conference on Teacher Education held in Nairobi, Kenya, in April and May 1973 (48). The following programme of the Universiti Sains, Malaysia, for the four year programme leading to the Bachelor of Science with Education is typical of the concurrent pattern (93, 290) to be found in many countries of Africa, Asia and the Pacific.

YEAR	COURSE
YEAR ONE	2 general education courses (42 hours each) + 6 weeks teaching practise in primary school
YEAR TWO	2 foundation courses (42 hours each) 1 methods course (21 hours science + 21 hours maths) + 6 weeks practise in biology
YEAR THREE	2 foundation courses 1 methods course (21 hours science + 21 hours maths) + 6 weeks practise in biology
YEAR FOUR	1 foundation course 1 mathematic methods course 1 science course (biology + either physics or chemistry)

The concurrent approach is also used in other regions. In Morocco and other French-speaking countries of North and West Africa, training used to be in faculties of science in universities with the pedagogy being given along with knowledge of the discipline. The stress, however, was on the biology component. More recently the trend has been to strengthen the pedagogical component. This has been possible because of the development of education departments with high standards and more often, because of the establishment of special training schools - the *Ecoles normales supérieures* (schools of education). These provide most of the pedagogical training for the senior secondary school and work in close co-operation with the universities that train in the content of biology. Graduates for senior secondary teaching take a four year degree programme and are examined in both biology pedagogy and classroom practise. The *Ecoles normales* also take entire responsibility for training biology teachers for the junior secondary school in a fully integrated two-year programme of biology and pedagogy (244).

In Belgium, universities provide consecutive training for the upper secondary school but secondary teachers who are to teach in lower secondary grades (pupils aged 12 to 15) are trained

in Higher Pedagogical Institutes. These Institutes provide two-year courses with the biological subject matter and foundation studies (General Methods) taught simultaneously. General Methods are taught by educational psychologists while the "special biology methods" are the responsibility of the subject specialist and form an integrated part of his course (113).

In Cameroon there is a further variant of the concurrent approach. Training in biology and in pedagogy go together, about 75 per cent of the time being given to the discipline. Training takes place in a teacher training college within the university. There are two cycles, the first of three years and the second of two years. The first cycle prepares teachers for the first cycle of the secondary school and the second cycle for the second cycle of the secondary school. Only one-third of teachers qualified in the first cycle proceed to further training in the second cycle (256).

Supporters of the concurrent approach cogently argue that it has less direct effect on the students' understanding of science (say biology) than on the opportunity provided for students to develop a personal position on certain aspects of teaching and education. Other arguments in favour of the approach are in terms of curriculum - the closer integration that is possible between academic and education areas, and the greater flexibility that is possible in course structure. This latter point is well illustrated by the very flexible concurrent programme offered by Rusden State College, Victoria, Australia (10, 42, 69). Rusden provides a four-year course leading to the award of a Higher Diploma of Teaching (Secondary). Students take eight academic subjects over the first two years in a School of Basic Studies and 18 units in the School of Professional Studies. Those specializing in biology can take units of education, including environmental education, in years three and four. Such graduates are qualified to teach secondary biology, physical science, general science, integrated science and environmental studies.

In summarizing this section, it is fair to say that both consecutive and concurrent programmes are being revised in an attempt to solve the central problem of balance between the demands of academic biology, general education and professional pedagogy. It is especially important that the content of the academic biology strand be relevant to teaching needs in terms of objectives, content and methods. Such training programme aim to develop a "whole view" of teaching competence embodying more than knowledge of subject matter or mere mastery of teaching technique (78, p. 217). It is significant that whole systems of education are redeveloping their approach to training and that, in general, it is the concurrent model that is gaining most support. On a regional scale, a recent report by Lewis (163) on trends in teacher education in Africa stresses the search for relevance and for closer integration between academic content and pedagogy. As an example of rethinking at a national level mention may be made of new trends in teacher education proposed for universities and training colleges in the Federal Republic of Germany (104, 246). The German universities are now introducing didatics of biology (i.e. methods of teaching biology) into the 'first' or 'scientific' phase of a four-year training programme for school grades 11 to 13. This is expected to provide an effective bridge between academic biological training and theoretical pedagogy. At the same time, the pedagogical strand within the 'first phase' is to be increased to one-third of the allotted time and the biological content is to be cut to two-thirds the present level. There will also be an increased role for basic sciences such as physics, chemistry, mathematics, biocybernetics and philosophy of science (246). The universities of the Netherlands are also currently reviewing their programmes of teacher education (232, 296, 297) in order to develop a closer relationship between scientific professional study and a deepened and broadened education preparation.

PATTERNS OF PRE-SERVICE TRAINING FOR THE PRIMARY SCHOOL

In most countries, the primary school curriculum in science is based on a broad programme of natural history, general science or environmental studies, and usually biology plays a central

role in such programmes. Teachers are generally trained in colleges of education that offer programmes from one to four years and almost all are designed on the concurrent model. The Certificates of Education awarded by Colleges of Education in the United Kingdom (12) and Australia (23) and the programmes of the Pedagogical Academies in the Federal Republic of Germany (246) are typical of the pattern. In some countries primary teachers are trained at universities or university-type colleges and this is particularly so in the United States (6, 289), but usually these programmes are also based on the concurrent model.

Training in biology for the primary school does, however, present special problems. In a report of a survey of teacher training for science teaching in the primary schools of the United States undertaken in 1969 by Blosser and Howe (24) it was stressed that 'individuals desiring to teach at the elementary school level cannot be prepared as specialists in all the subject matter areas which they are called upon to teach in a self-contained classroom, at least within the four-year preparation period'. Part of the answer may be in the careful selection of biological topics to be included in such a programme so that time is not wasted on irrelevancies. This suggestion is supported by a study completed in 1973 by Frosch (89) of courses at University of Oklahoma which showed that elementary teachers and college faculty differed markedly in their views of which biological concepts were of importance in the training programme. Frosch also implies that much of the training of the primary teacher in the methodologies of the teaching of biology may need to be deferred to the in-service phase.

In many developing countries, training for teaching science in primary schools must, for reasons of both supply and cost, be reduced in length. Secondary schooling in itself is taken to be part of the training. In many such countries, experience in the primary school may qualify selected teachers for sandwich-type, concurrent, or in-service programmes which, if successfully completed, would enable them to teach at higher levels of the system. A typical programme is the scheme offered by the Ministry of Education in Afghanistan (174). This is as follows.

- After school Grade XII students train for one year at a Teacher Training Institute (Grade XIII).
- After two years of experience in primary school selected teachers may follow a one-year course at an institute (Grade XIV) and so qualify to teach in middle schools (upper primary).
- Those teachers who have qualified as above and who have taught in middle schools for at least two years are admitted to another year at the Teaching Institute (Grade XV) and may then teach in secondary schools.

Countries such as India, with special problems of numbers at the primary school level, have had to find even more drastic alternatives (267). The Basic Teachers Certificate (BTC) in India is of one year's duration only, qualifying teachers for the primary grades (I to V). Entrance qualification is Grade X of the High School. One BTC teachers' training school in each district has been converted into a science normal school and those seeking admission must have passed in a science subject at high school. In these science training schools, certain general courses have been eliminated to give place to science. With the help of Unicef, the training schools have been equipped with science kits. Graduates of these science normal schools are qualified to teach primary science. The system is supported by in-service development.

TRENDS IN BIOLOGY TEACHERS TRAINING PROGRAMMES TOWARDS CONTENT WITH GREATER RELEVANCE TO PERSONAL, SOCIAL AND NATIONAL NEEDS

Biological programme within training institutes are rapidly revising and reviewing their content to make it more relevant to personal, social and national needs (236). A strong emphasis has been given in recent years to environmental matters such as human ecology, population studies or pollution. The environmental programme of Rusden State College has already been discussed

(10, 42, 69). A similar programme is provided by Governors State University, Illinois (79). The University of Colorado now has a successful programme on International Environmental Problems (273). Columbia Teachers College New York structures a biology programme around a core of population education (126, 127).

The Delaware Department of Education has sponsored a series of in-service activities designed to promote environmental awareness and responsibility (60). In Australia, the Queensland Department of Education has organized workshops to train teachers in the effective use of environmental studies centres that have been established throughout the State (41). The Institute of Education in Mauritius offers in-service courses in environmental studies for teachers of primary science (9). Lawrence (155) in a review of environmental studies in the United Kingdom claims that in-service courses are required to assist teachers of all levels become generalists rather than specialists. The Department of Education in Saskatchewan provides in-service training in environmental and field techniques (218). The University of Abidjan, Ivory Coast, includes courses in ecology of special relevance to the region (17). Students of the University of Zambia are trained to respond to local situations and to develop environmental resources such as school gardens and ponds, and to establish clubs for pupils especially interested in farming or other science-based activities (243).

One other related trend is the change occurring in pre-service programmes to accommodate the expressed need of students to be involved in the design and administration of their own courses. Students now are often involved in planning courses and in evaluating the effectiveness of their programmes (133, 134). This has, on the whole, tended to make courses more relevant to individual and social needs.

LINKING PRE–SERVICE AND IN–SERVICE PROGRAMMES TO ENSURE THE CONTINUING EDUCATION OF THE BIOLOGY TEACHER

Two points stressed by Unesco in the Report *Learning to Be* (78) are first, the need to break down the divisions between formal and informal systems of training and, second, the fact that teachers trained today will still be exercising their profession after the year 2000. These points imply the development of closer links between pre-service and in-service programmes - between initial training and cycles of retraining which will ensure the continuing education of the biology teacher.

In the past, in most parts of the world, retraining programmes for teachers have not been highly organized and have generally had poor reputations (115). The older style programmes have, in the main, taken the form of short courses, often sponsored by voluntary groups or agencies other than those responsible for pre-service courses. Yet the need for in-service programmes is unquestioned. Paul Mohr (189) writes as follows.

'In-service programmes should encompass these goals:

- increase the effectiveness of all teachers, trainers, and trainees;
- develop the interpersonal growth of teachers;
- provide means of self-evaluation;
- change patterns and methods of directing learning experience;
- improve utilization of educational resources;
- improve teacher-child relationships;
- provide opportunities for discussion and sharing of ideas;
- provide adequate feedback about the effectiveness of their teaching;
- provide opportunities for continuous growth and to extent competencies;
- assist practicing teachers to become more proficient in the use of media;
- obtain maximum impact by teaching entire staff of a school;

- involve teachers in the planning and implementation of in-service courses;
- provide atmosphere which facilitates growth and change;
- involve teachers and teacher groups in research and experimentation'.

An especially important aspect of such goals for in-service education is in relation to curriculum development. The key role of teachers in implementation and development of new curricula has now been recognized. The relationship between these aspects of a teacher's role and in-service programmes is not so clearly appreciated. In this regard, the work of Rubin (1964) in the United States (242) provides some useful guidelines. Rubin concludes that it is the task of leaders of curriculum development projects to set forth what they expect from in-service education with regard to the new programme; provide the realistic wherewithal for the achievement of these expectations; arrange for the release of individual teachers from those things which seem to restrict him or her; and devise systems to evaluate the effectiveness of the change. These concepts are further expanded and developed in the book edited by Rubin *Improving In-service Education* published in 1971 (241).

The foregoing statements imply that there is urgent need for close co-operation between pre-service agencies; curriculum workers and in-service agencies; and that the more intimate the link, the stronger the chance of there being meaningful continuous professional development of the teacher (274). Few, if any, formal programmes have as yet been developed that bring together the complete resources of a community in a coherent and systematic structure for the continuing education of biology teachers as recommended by Unesco in *Learning to Be* (78). Links between pre-service and in-service training, are, however, strengthening, as is the degree of overall community involvement, as shown by the following examples.

California State University at Fullerton involves teachers in the selection of trainees and screens potential trainees by evaluating reports of structured visits to selected schools (280, 281).

In Sweden, certain staff members of the Teacher Training College in Uppsala teach in local primary schools to assess the problems of implementing a new primary science curriculum. The feedback obtained helps them structure their training programmes (303).

In Australia, the State College of Victoria at Hawthorn involves practising science teachers in the development of materials used for the pre-service programme by conducting residential workshops where teachers try out experimental materials developed by college staff (164). Macquarie University in Sydney (173) and Monash University in Melbourne (101) have for some years conducted in-service seminars for their own graduates to help them implement ideas gained in training and to obtain feedback on the effectiveness of the pre-service courses.

In Ghana, links between pre-service training and in-service are maintained by the biology panel of the Ministry which advises lecturing staff on teachers' needs and helps the university plan both pre-service and in-service activities (211).

The general problem of strengthening links between pre-service and in-service through training programmes for within-school supervisors of trainees has been faced by many institutions. Courses offered by Digby Stuart College in the United Kingdom (65) and by the New South Wales Department of Education in Australia (91) are useful examples.

In Northern Ireland there are both formal and informal links between pre-service institutions and in-service units such as Teachers' Centres. For example, there is a cross-membership of school boards, subject boards of studies and of working parties and committees, between the Education Centre and the Departments of Biological and Environmental Studies at the New University of Ulster. Other links include cross-teaching; sharing of resources; consultancy and use of biology students in experimental programmes (270).

One of the more imaginative approaches to community involvement in the continuing education of science teachers is the Outdoor Biology Instructional Strategies programme (OBIS) of the Lawrence Hall of Science at Berkeley, California (77), which trains community leaders for field work in biology, catering for pupils, parents and teachers and indeed any interested

citizen.

Another trend, reported by David Smith, is to strengthen community links by prefacing entry into college training by some type of work experience (254).

These changes, of course, require the staff of pre-service colleges to themselves change and adapt to new technologies and philosophies. Many systems are now providing retraining programmes for college faculty and programmes in Australia (180, 182), the United Kingdom (71, 97), and the United States (58, 59, 76) provide useful models.

In concluding this section the following quotation from the report by Unesco published in 1972 on *The School and Continuing Education* (287: p. 177-78) is perhaps appropriate.

'Yet it is clear that education cannot be merely a preparation for life, and extend over a limited period; it must be a life-long process. Man today never stops learning. Education is losing its purely preparatory character and has become an aspect of living, a way of life. It is a vital constituent of all other specialized social activities. It therefore deals with ideas, experiences and social attitudes which have nothing to do with childhood and youth; and so it is losing its formal side and is ceasing to be 'separated from life'.

If this philosophy holds true for the average citizen, how much more should it be true for the teacher, whose task it is to help others learn.

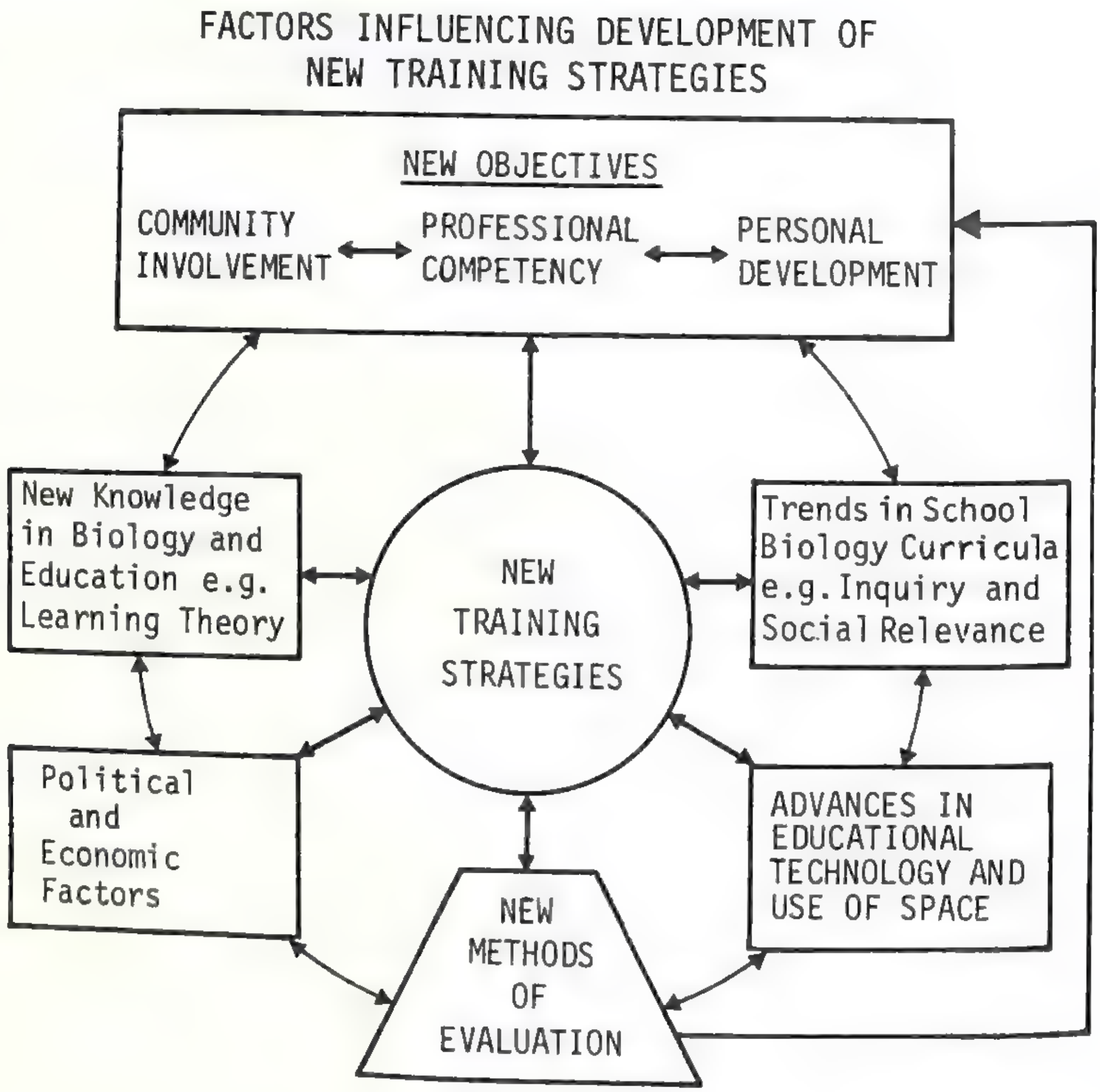
TRENDS IN THE STRATEGIES FOR TRAINING AND RETRAINING BIOLOGY TEACHERS

As both pre-service and in-service programmes of teacher education seek more emphasis on teaching competency and on greater professional relevance, there has been a rapid change-over from traditional lecture and tutorial methods to a wider range of training styles and strategies. The following statement of policy by the European Community is typical of a world trend. The Community's Directorate-General for Research, Science and Education reports a growing concern among teacher educators of member countries for the development of a "less formal and more imaginative pedagogy". This in turn has involved intensive and widespread programmes of in-service training to develop in the teachers the new skills and attitudes which these innovations demand". (247). The diagram overleaf summarizes some of the factors influencing the development of strategies for the training and retraining of biology teachers. Newer strategies and techniques for the training and retraining of teachers have been reviewed by Finch (85), Harris, Bessent and McIntyre (107), Johnson (131), Rubin (241), Tisher (275) and Watkins (304) and some accounts of new strategies are included in the reports of the Commonwealth Conference on Teacher Education held in Nairobi in 1973 (48) and in the final report of the Regional Experts meeting on the Asian Programme of Educational Innovation for Development, Bangkok 1974 (288).

The following section describes some trends in the use of newer training strategies and gives examples of their application in selected countries.

Training in understanding objectives is changing to training in writing objectives - generally expressed (but not always so) in behavioural terms

The emphasis on careful formulation of objectives for school curricula and for learning sequences has, in recent years, been reflected in programmes of training and retraining of teachers (105, 235). Most courses for teachers emphasise the importance of clearly stated objectives and most distinguish between objectives expressed in behavioural or non-behavioural terms. The widespread use of audio-tutorials (185, 223) and more recently of modules and minicourses (180, 224), each with their 'systems' approach, has further emphasised the key role of objectives (audio-tutorials and minicourses are defined and discussed overleaf).



More recently, stress has been on training student teachers to write objectives for their own courses, practice lessons, and for units of work. In Tanzania, for example, workshops held at the Institute of Education Dar es Salaam train teachers in the writing of behavioural objectives for new biology curricula (184, 187). At the University of Manchester (U.K.) biology teacher trainees are encouraged to write specific objectives for lessons and are given checklists of objectives for self-evaluation of their teaching effectiveness (53, 54). In the United States, the undergraduate programme at Ohio State University in science education consists of five 'quarters' or semesters each for a specific level of the school system. Each 'quarters' is defined by a checklist of behavioural skills which must be acquired by trainees (215).

Diversification of conventional forms of practice teaching to make more effective use of time and to include more vicarious experience - films, audio recordings, microteaching and video-replay

Recent reviews of the practice teaching component of pre-service training by Stanton (257), Stones and Morris (260) and by Tibble (274) have highlighted the following three trends. Firstly there is an increasing tendency to extend the time spent in schools to acquire practical skills, especially in concurrent programmes. A second trend is in the nature of supervision. Increasing attention is being given to appointing and retraining within-school master teachers or supervisors. A third trend is an attempt to relieve the pressure on training for laboratory or demonstration schools by spreading training more widely and by finding ways of complementing supervized school experience by use of simulations such as 'model' video programmes combined with elements of microteaching.

By 'model' video programmes is meant the recording on video-tape of good examples of the use of specific teaching skills such as questioning, closure, or reinforcement and making these available for replay and study by trainees. The 'model' tapes are prepared by highly skilled practising teachers. Micro-teaching, on the other hand, uses a similar technique but with the trainee himself as the subject. Specific incidents of classroom management or of the application of teaching skills are practiced by trainees either with actual classes or in simulated classroom situations with fellow students playing the role of pupils. These incidents are recorded, replayed and discussed by the trainees. Microteaching is now widely used both to reinforce skills developed during practice teaching and as a vicarious substitute for certain elements of school experience. Two recent books by Turney *et al.* emphasize these trends (282, 283). Kenya provides an interesting example. Microteaching used to train teachers at the University of Nairobi has proved to be effective in developing teaching skills. It was introduced to replace the first external teaching practice normally held at the end of the first year of the B.Ed. programme (112).

The effectiveness of microteaching in the retraining of teachers has been convincingly demonstrated by Perlberg *et al.* who have shown that it can change student-teacher behaviour from teacher-centred verbal imparting of knowledge to pupil-centred analytical thinking and non-verbal activity (217).

The trend towards extending the time spent in schools is well exemplified by the system of training in France where 27 weeks of school experience are now required in the training year (121). In Canada, the University of Western Ontario, London, provides four continuous months of practice teaching in schools, followed by four months of college instruction together with a residential programme of 3-4 days at a biological field centre (214). Some systems require trainees to work at different levels of the school system. For example, practice teaching for secondary school biology teachers during the Diploma in Education course offered by Queen's University, Belfast, includes two weeks in a primary school and ten weeks in a secondary school (83). In the United States, there is a trend throughout California towards greater use of off-campus training facilities, and the majority of teacher preparation takes place in local schools with practising teachers doing most of the instruction (280, 281).

The supervision of practice teaching presents problems. In large training institutions the staff cannot always visit all students in schools. There is, therefore, a trend towards the appointment of special "master teachers" or trainers within schools to supervise trainees. In most Californian schools, for example, the supervising teachers are often especially employed on a part-time basis by the training institution (280, 281). Another example is the case of the Flinders University of South Australia which has arranged for the appointment in training schools of Special Deputy Headmasters who organize teaching practice. This has led to an increase in the practical experience of students. As the Special Deputy, however, is not necessarily a biologist, the role of the classroom teacher is also of prime importance (167). The problem has been approached differently in Malaysia. The Universiti Sains Malaysia has developed an 'education student internship' in

which selected teachers act as honorary tutors to students during school practice. Heads of schools and tutors participate in joint seminars with academic staff on aspects of science education and curriculum (93, 290).

If ordinary school personnel are to be given the responsibility of supervising trainees, they themselves need special retraining. In Australia, the Teacher Education Programme at Macquarie University offers retraining programmes for 'master teachers'. These courses use model films, video-recordings and microteaching methods to familiarize master teachers with the technologies being used in training the students they are to supervize (173).

Turning more generally to the question of retraining, there is a noticeable trend towards the application of microteaching methods in in-service programmes. Two examples from the United States illustrate how these techniques can become the basis of a whole system of in-service education. The first example is a programme to improve the quality of the staff of a training college. The staff training programme for members of faculty (including biology education) mounted by the University of California (Berkeley) has three components. Each participant is video-taped while he teaches. He and the course instructor then analyse the personal video-tape using a set of prescribed criteria. Weekly seminars are also held with people from the same discipline (biology) to discuss teaching problems and to view representative video-tapes (194, 198). The second example is concerned with the upgrading of teaching at the school level. Microteaching and video-taping of lesson sequences are used extensively throughout the secondary schools of Illinois to improve the quality of science education through the development of skills of science teaching. Self-rating devices are used to evaluate the effectiveness of the retraining (318).

The discussion so far may suggest that microteaching, whether used for initial training or as part of an in-service programme is of necessity an expensive technique involving a great deal of elaborate electronic equipment. This need not be the case. While audio or video recordings of teaching incidents are very effective, they are not essential. In Malawi, microteaching methods have been successfully employed without audio-visual technology. Students of Soche Hill College of the University of Malawi present a prepared lesson of ten to fifteen minutes to a supervisor and peers, the latter divided into a simulated class and a group of observers. The performance is critically analysed by observers and supervisor (154). While lacking the facility to permanently capture every aspect of the teaching incident, this method adequately focuses attention on the improvement of specific skills.

An appreciation of student differences is leading to linking instructional techniques to individuals and groups, by matching resources and strategies with needs of individuals, e.g. programmed instruction, audio-tutorials, and multi-media training kits

Programmes of teacher education have, for many years, tended to cater for individual differences in background and rate of learning by providing opportunities for students to proceed at their own pace. One of the first techniques employed to achieve this was programmed instruction. More recently it has been recognized that conventional programmed learning only caters for differences in rate but does not allow for preference in the style of learning or in the medium of instruction.

There has, therefore, been a rapid increase in the use of audio-tutorials and, more recently, in the use of less highly structured multi-media resources. Audio-tutorials were developed in the United States in the early sixties by Postlethwait at Purdue University. In an audio-tutorial approach, the content of a course is broken into units or modules. Students work at their own pace by studying a variety of learning materials - specimens, films, video-recordings, pictures, scientific apparatus, etc. - co-ordinated by audio-tape recordings (221, 222, 223 and 224). The audio-tutorial which began at Purdue in the School of Botany is now widely employed in the School of Education of that University where it is used effectively in the pre-service training of

biology teachers (140). The audio-tutorial recognizes that students not only work at different rates but can learn from a wide variety of media. More recently, however, the 'closed' structure of an audio-tutorial has been modified by providing students with learning kits presented in a wide variety of formats and media so that they may select media most appropriate to their learning needs (8, 180, 298).

Other self-paced systems now more widely used in programmes of teacher education include the contract method and the Keller Plan. The contract method places responsibility for learning on the student by allowing him to proceed at his own rate to achieve mutually agreed objectives. The student 'contracts' to 'master' the objectives. The Keller Plan is a self-paced, modular scheme that involves the use of proctors (originally undergraduate students) to help in testing and tutoring and to increase personal contact in learning. A useful review of research related to some of these personalized methods in science education is given by Novak (210) and Bowman has reported a useful case study (27).

Example of personalized instruction in the training of biology teachers are available from many countries. In the Philippines, students of De La Salle Training College in Manila are given a series of 'free-lab' exercises that they complete on their own initiative. The approach is appreciated by students as it recognizes maturity and allows for creativity (3). In Canada, the University of Toronto includes a modified 'contract' system in its pre-service programme. Apart from core activities, students "contract" to complete a wide range of optional activities. This programme is self-paced and caters for differences in background and interest (152, 153). In the United States, the first-year biology programme at the State University of New York at Stony Brook is based on the Keller Plan (261).

Some institutions have combined several methods of personalized instruction into a complete training programme. The Department of Biology of the Western Australian Institute of Technology, in its programme for first-year students, uses both audio-tutorials and the Keller Plan to personalize instruction. In the latter case, the third-year degree students act as proctors or leaders of small group tutorials and also establish the levels of mastery for each module of work. They determine when each student may proceed to the next unit (43).

These approaches are also useful in programmes of in-service education. In the United States, the Oakland Community College's Teacher Improvement Project TIP retrains teachers in the East Lansing district of Michigan in personalized instruction by developing an educational prescription for each individual child. This involves what is termed a 'cognitive map' for each learner. Diagnosis also includes matching the learners' needs with appropriate media and resources (172, 245).

An interesting recent trend is for teacher education institutions to come together to share resources for programmes of personalized learning. Colorado State University, for example, has produced multi-media training kits for use by biology trainees in thirteen Community Colleges of the State of Colorado. Most include colour video-tapes of single concepts (44, 135, 136).

The excursion or field trip is evolving into training programmes for environmental and community analysis

Programmes in the training and retraining of biology teachers have frequently stressed the need for training in the skills of field work (17, 34, 35, 41, 132, 187, 188, 196, 218). More recently, this type of emphasis has broadened to include training for teaching about wider issues such as environmental and community study (60, 77, 79, 125, 127, 145, 229, 268, 313).

There are numerous examples of this trend. The Field Study Centres in the United Kingdom, the United States, Australia and Canada are well known and all provide courses for teachers. In Japan, teachers attending Science Education Centres are trained in the techniques of field work and environmental studies (196). In Mauritius, two hours of school time per week for

twenty weeks are used to train primary school teachers in three centres in the techniques of environmental studies for primary school courses (9). The Institute of Education in Singapore produces resources for environmental education and gives trainees special preparation in this area (313). Teachers' colleges in Sri Lanka help to organize community projects, co-ordinate school programmes, and train students in principles of community involvement (48: p. 297).

Two trends emerging in Australia perhaps suggest ways of ensuring that systematic programmes of pre-service training and continuing education in field work are maintained. The first is to establish field centres in the grounds of training colleges. Newcastle College of Advanced Education proposes to establish such a field studies centre on its campus for the training and retraining of teachers in the techniques of environmental teaching (170). The second trend is to train teachers in the effective use of their local areas. The Queensland Department of Education has appointed a team of experts to visit schools and help teachers map the environmental resources of the district. Workshops are also provided to train teachers in the skills of field work and to help in the structuring of environmental programmes (41, 229).

Conventional block timetabling is leading towards minicourses and other more flexible ways of using time

Individualized or personalized approaches to training (see above) are one way to break away from conventional approaches to the use of time in pre-service and in-service programmes. Another technique that has gained popularity in recent years is the introduction of flexible units of work, termed modules or minicourses. This approach developed as an outcome of the audio-tutorial method (223) and has been used extensively by Postlethwait at Purdue University (224). Characteristics of minicourses have been defined by Postlethwait and Hurst (221, 222) and by Meyer (180). They are self-contained self-paced units of work, with carefully defined behavioural objectives. They usually involve multi-media formats and students learn through activity. Each module or minicourse is of short duration. As originally developed, they were designed as part of a coherent programme of study for pre-service trainees. In this context, pre-tests are important. Students in such courses start a given module by taking a pre-test to determine if they have the necessary knowledge and skills. More recently, the minicourses format has been used to develop particular skills in programmes of in-service education. In such courses, the pre-test is less necessary (66, 180).

Modules are now widely used in both pre-service and in-service programmes of biology teacher education. They are, for example, quite generally used in Japanese universities and schools (197). Salisbury College of Advanced Education in South Australia trains biology teachers by offering a core of common materials and a programme of optional modules on topics such as population, pollution or Australian mammals (11). Student teachers of the Department of Natural Science of the University of Chile study self-contained modules on such topics as local ecology and marine biology (34, 35). In New Zealand, in both the universities of Auckland and Christchurch, graduates in biology are trained for teaching during a Diploma programme with modular timetables. These provide students with a wide choice of units on content, teaching theory and method (216). In the United Kingdom, the Science Teacher Education Project (STEP) has produced multi-media modular units on science teaching skills for use in college programmes and by students in schools during teaching practice (110, 111, 248, 264, 265). At the University of Southern Illinois at Carbondale, competency-based programmes are individualized using flexible modules on topics such as 'the evolution controversy' or 'statistical methods for biology teachers' (316-319).

Small group work is evolving into a study of interpersonal relations and leads to sensitivity training

In almost all countries of the world, both pre-service and in-service programmes of teacher education place less emphasis on formal lecture methods. The trend is towards learning through activity and through direct involvement in teaching. Most work is now undertaken in small groups. Even the conventional tutorial has become more varied with a greater emphasis on activity than on discussion alone.

As training programmes move away from conventional lectures and tutorials, there is a trend towards a more varied approach to small group work, including some emphasis on personal development and sensitivity training. Some of the STEP emphasise these trends (111) and they are also discussed by Rubin (241). Sensitivity training involves developing in teachers a greater awareness of their own personalities, and trains them to be sensitively aware of the personalities of others and of how personalities may interact.

This trend is well advanced in France where the National Ministry of Education is encouraging training institutions to introduce courses in personality development for science teachers (45). In the United States, there are also examples of training programmes in this area. The programme in Minneapolis is especially well developed. Counselors in selected Junior High Schools are retrained to adopt the role of team member and facilitator and to encourage interactions between pupils, teachers and parents. Counselors arrange meetings, workshops and classroom visits within the schools (130).

A related problem is the need to retrain teachers entering the teaching profession from other countries so that they become more sensitive to the social customs of their new country. Many universities and colleges of Africa provide such retraining programmes. In the United States, overseas students (including biology teacher trainees) may attend special seminars and individual tutorial programmes at the International Training Institute in Washington, D.C. to help bridge differences between life and education abroad and in the United States (251).

Classroom observation is developing into interaction studies

Observation of teaching in classroom by supervisors during practice teaching (260) and as a method for evaluating the effectiveness of new curricula (184, 187) has long been established. More recently there has been a trend to use observation techniques to analyse the personal interactions occurring in the classroom and to use the evidence obtained to train and retrain teachers in the application of pupil-oriented strategies (226, 260). Most interaction studies are based on methods developed by Flanders and develop indices of the amount of 'teacher talk' and 'pupil talk' in defined categories. Practical accounts of the method are given by Stones and Morris (260), and by Rubin (241). Pogirski and Voss (219) have suggested that findings from interaction studies should become the basis for the in-service training of biology teachers. A practical example of the use of interaction studies is provided, in Australia, by the Centre for Advancement of Teaching at Macquarie University. During minicourses for teachers (see above) video-tapes of teaching sequences are analysed for patterns of interaction between teacher and pupils. The information obtained is then used in workshop situations to help teachers develop techniques for improving the general tone of the classroom (180).

The 'Teachers' Guide' is evolving into special pre-service and in-service training modules for new curricula

Teachers' guides for specific learning resources and courses of study are well established and

usually provide additional interpretative information for the teacher (for example, the excellent Teachers' Handbooks for the Biological Sciences Curriculum Project - see reference 99). More recently these guides have been developed into structured training manuals. Examples of teachers' guides containing an element of training have been produced or are in the planning stage for new biology courses in Ethiopia (305), Kenya (269), Malawi (176), Nigeria (291, 308) and Saudi Arabia (5) and for the Unesco Pilot Project for the improvement of biology teaching in Africa (187, 188) to name just a few.

The following examples are representative of this trend. The first example (from Australia) is related to the introduction of a new science curriculum in New South Wales. Multi-media, self-contained training modules have been developed by the State Department of Education for the retraining of science teachers. Modules include training in the skills of organizing a teaching programme, setting up a system of assessment and assessing affective outcomes (207). The second example (from Indonesia) is specifically designed to help teachers use local resources. In Irian Jaya, the Ministry of Education, has sponsored the production of a training manual in the manufacture and use of home-made equipment for teaching a new biology curriculum (22).

Simpler aspects of role playing are developing into more sophisticated forms of educational games and other simulations

Role play has been recognized as a useful device in the training of biology teachers. A manual produced by Lehman in 1970 (160) contains helpful suggestions for role play situations for training in inquiry teaching, self-pacing, interpersonal relations, and the social implications of science.

More recently there has been a growing interest in more general forms of simulation. Cruickshank and Broadbent (55) have researched into the effectiveness of simulation by identifying thirty-one teaching problems and have developed activities for students to investigate these problems through video-taped and filmed incidents, role play, written incidents and various combinations of these. They conclude that simulation is 'an unqualified success as a teaching device that motivates and involves students'. Microteaching and video-replay as substitutes for teaching practice are forms of simulation that have already been considered. The use of simulations of general teaching problems has also been developed by the Science Teachers Education Project in the United Kingdom (248). In Nigeria, the Science Teachers Association is at present (1975) developing simulation activities for students in training. Simulations of problem situations in teaching, using photographs and tape recordings, are to be used to stimulate discussion of teaching methods (291, 308).

An especially interesting use of educational games has been developed by the Inter-University Biology Teaching Project in the United Kingdom. This project, begun in 1969, involves five universities which have worked together to produce self-instructional games for training biology teachers. These games place learners in the position of a scientist who must solve certain scientific problems, for example an ecologist trying to determine factors influencing distribution of algae (278).

Group co-operation is moving towards team teaching and team training

While team teaching has been widely used in primary schools it is only recently that it has been used extensively in the training and retraining of biology teachers. Rubin (241) gives some general examples, and the environmental advisory teams of the Queensland Department of Education, previously reported, are of direct relevance to the in-service education of biology teachers teachers (41). Fenwick English (75) has recently presented a useful discussion of the possible

roles of team members in school-based training programmes.

Team teaching methods involving teaching hierarchies, utilization of various training skills, flexible strategies and flexible use of time and space are a feature of the Macquarie University minicourses for teachers, previously reported (180). Team teaching is featured in training programmes in the University of Guyana (149). In the schools of Coventry (United Kingdom) the technique has been used to provide effective retraining programmes within schools. Hierarchical teams led by especially appointed curriculum developers, train together to develop within-school curricula and staff improvement programmes (57).

Laboratory and classroom organization and strategies are evolving into techniques of open-plan education

While open-plan schools are now well established in many school systems (179), very few teacher education institutions have as yet been designed on this basis. In the open-plan design, walls and other traditional 'barriers' are flexible and teaching areas can merge into one another. The open-plan system has led to many innovations in primary and secondary schools such as team teaching, integration of the curriculum and greater use of educational technology (179). Some of these aspects have been analysed in a recent research study reported by David Engleherdt (74). His report shows that provision of innovative space is a stimulus for innovation in teaching style and so this approach must not be ignored as a factor in the retraining of teachers.

More recently open-plan thinking has influenced training colleges. An example is provided by the Science Laboratory complex of the Sturt College of Advanced Education in Adelaide (South Australia). This complex will not have classrooms or separate laboratories for individual sciences. A large flexible space with movable equipment, furniture, and resources will encourage integration of content and method. The central laboratory will be ringed by special purpose rooms for aspects such as environmental studies, optics, aquaria, and specialized project rooms (263).

Project work is evolving into genuine research study

Assignments and projects have a long established tradition in pre-service training programmes. Student research has, however, usually been limited to the special few who have elected to take a biology degree with a research major (51). A recent trend is to build research-type experience into the teacher training strand of the pre-service training. If teachers are to understand processes of inquiry there is a strong argument for including a research-based project in their training.

In Nepal, biology teacher trainees taking the Diploma course at Tribhuvan University must complete one semester of self-directed project work. In the degree course, this is replaced by one semester of original research into a biological problem of immediate relevance to their needs (227). In the fourth year of the B.Sc. with Education of the University of Zambia, biology majors complete modest but original research study and present a mini-thesis of sixty pages. The topic chosen for research must be relevant to the school curriculum and must be researched at a high level of scientific rigour. As well as the thesis, there is an oral examination, accompanied by a display of the equipment and material used in the research study (243).

Some involvement by practising teachers in research, especially in aspects of curriculum evaluation, is now quite widespread and has an obvious in-service role (184). In Malaysia, for example, biology teachers have become increasingly involved in curriculum development and developers now use practising teachers to assist in curriculum evaluation. This is undertaken in in-service courses as well as when teachers return to the schools (250).

Assessment by formal examination is changing to assessment of the formative development of specific teaching skills and of more general teaching competencies

The traditional modes of examining and grading based on terminal written examinations in biology method (didactics and pedagogy) have now tended to be replaced by continuous assessment of projects, assignments and units of work. More emphasis is being placed on assessing attainment of teaching skills and of other professional competencies. The assessment of teaching skills, however, has been under critical review in recent years since the criteria for rating and grading trainees during practice teaching have, at times, been vague and ill defined (260 p. 28 and 29). Studies by Pogirski and Voss (219) and by Dieter (63) have further emphasised such difficulties. The problem has been reviewed recently by Thompson (271) who advocates a clearer statement of objectives as a partial solution. The assessment of the achievement of highly specified skill objectives is now more generally accepted (193).

In many biology teacher training programmes, students are encouraged to evaluate the teaching in their own courses (156, 199) and this helps to provide insight on competency. The self-inventory produced by the National Science Teachers Association of the United States (202) is an interesting attempt at encouraging teachers to evaluate their own teaching competency and is thus a useful in-service device. Assessment of the teaching qualities of training staff colleges and universities is an important general issue (73) related to the whole question of training and retraining at that level.

Stress on cognitive aspects of teaching is changing to training for attitudinal development with special reference to their application to problems

Many training and retraining programmes now place considerable emphasis on developing teachers' attitudes to such questions as inquiry learning, environmental issues, personal adjustment and perceived role (253, chapter 6). Some programmes developed to change attitudes towards social questions such as population control and pollution of the environment have already been discussed (126, 127). Wilson has reviewed problems of changing teachers' attitudes towards inquiry learning and the philosophy of science in countries of Africa (310). Jungwirth and Dreyfus have considered aspects of the same problem in Israel (138).

Examples of specific programmes include courses at Christchurch Teachers College, New Zealand, and at the University of Colorado (USA). The courses at Christchurch are especially designed to change attitudes so that trainees will accept leadership roles and responsibilities. One device is to use self-selecting programming of time and resources (40). A course at the University of Colorado (USA), available to biology teacher trainees, stresses international environmental problems. It is designed to assist students make value judgments about population control and food needs in various parts of the world, especially in developing countries (273).

Inquiry and problem-solving emphasis is enlarging its perspective to include training for creativity and divergent thinking

Inquiry learning and the problem-solving approach in training has been reviewed elsewhere in this chapter. There is a trend to further extend this type of approach by developing the skills necessary to foster creativity and divergent thinking. A recent article by Lucas (168) surveys the relationship between creativity, discovery and inquiry in science education, and Stenhouse (259) has reviewed some recent research on scientific creativity. Cases of approaches to training biology teachers for creativity are not well documented but most seem to start from inquiry-type situations (49, 50). Stones and Morris (260: p. 116) report interaction studies by Amidon with

student trainees at Temple University, USA, on how effective questioning can lead to divergent thinking, and Razik (235) presents a useful model of teaching as 'problem resolution' (p. 127-135).

A specific example is provided by the Patterns of Enquiry Project of the Ontario Institute for Studies in Education, Canada. This is intermediate between training for inquiry and training for creativity (49, 50). Finegold (86) reports the effective use of short sections of scientific research material in stimulating discussion of the processes involved in the research.

Analyses of given courses of study is changing to development of skills of curriculum construction

Training and retraining of biology teachers has traditionally included some detailed analysis of established curricula such as the Nuffield programmes (144) or the Biological Sciences Curriculum Study (99). More recently, teachers in pre-service courses have been trained in the processes of curriculum development (235) and practising teachers have been involved more in the development of new courses. This latter aspect has been reviewed elsewhere in this chapter and will be considered again in the next section on forms of in-service training. Mention is made here, however, of the highly successful Unesco Pilot Project for the improvement of biology teaching in Africa. This project fostered the development of study groups in many African countries. These groups, mainly of practising teachers, arranged workshops and other in-service activities to develop and evaluate new biology curricula (187, 188, 287).

Learning to use resources is widening its scope to include training in the production of resources

With the advent of low-cost systems for photography, audio and television, together with the development in most training and retraining institutions of media resource centres, there has been an increasing trend towards training in the production of both print and non-print learning materials. This trend has been accelerated by the involvement of teachers in the development of curriculum resources through attendance at developmental curriculum workshops.

The Institute of Education in Singapore provides Saturday lectures and field courses on environmental education. Staff and students work together to produce resources for environmental studies for both pre-service and in-service needs (313). The University of Leeds (United Kingdom) requires all biology teacher trainees to complete three 'method units' and most of these involve production of resources. For example, students make working models or charts, organize a field course or construct a linear programme on a biological topic (158). Workshops sponsored by the Newark School District (USA) have trained local teachers in the development of their own audio-tutorials and minicourses (26). Jersey City State College (USA) requires each student training in order to teach elementary school science to assemble a multi-media learning kit or 'Unit Box' on a specific topic. Some elements of the kit must be developed by the students and others may be purchased. The kit includes printed materials, projectuals, audio-tape, cards, test items and a teachers' guide (16).

Training in the production of simple equipment and scientific apparatus is also important. In Thailand, for example, workshops conducted by the College of Education at Prasarnmitr have been successful in training teachers who can make equipment from simple inexpensive local materials such as bamboo (162).

Conventional training in communication skills is changing to training for making full use of educational technologies such as radio and television

An appreciation of the role of media in communications has led to wider applications of educational technology in teacher education (4, 285). The application of the systems approach with its emphasis on behavioural objectives, performance criteria, multi-media modules and evaluative feedback has given educational technology a rationale and has increased its use in training (235). Audio-tutorials are now used in wider settings such as training for field work (185) and muti-media modules are used to train in problem-solving and inquiry skills (87). Useful reviews of these and other applications of technology to the training and retraining of teachers are given by Perlberg (285: p. 222-239). Allen (4: p. 291-294) and by Lee and Lewis (157).

Many institutions now provide training in the production of audio-visual resources. Mini-courses offered by the Centre for Advancement of Teaching at Macquarie University (Australia) train teachers in the production and development of transparencies, slide sets, audio programmes and video materials (180). The National Audio-Visual Aids Centre in London provides a consultancy service, an equipment supply service, an audio-visual aids library, and an extensive in-service training programme in educational technology for teachers of all levels (200, 201, 238).

Educational broadcasting by radio and television has been used effectively in many countries for the training and retraining of teachers - the Open University model in the United Kingdom being an exemplar. Other examples include general interest programmes for teachers and school broadcasts in the United Kingdom (94, 108); and broadcasts for schools and teachers in India (70, 147, 148), Kenya (146) and Mauritius (186). An experimental programme mounted by Illinois State University successfully training teachers and instructors in the techniques of producing television biology courses (301). The Ministry of Education of Kuwait provides in-service courses to train teachers in educational technology, including the effective use of educational television (180). Fifteen countries of the Caribbean have participated in a training programme for the staff of twenty colleges of education in the use of closed-circuit television and other media. Stress has been on the production of resources and on using technology for the solution of educational problems (36).

Research findings by Dieter and Hounshell (64) in respect of the resources available to more than forty biology teachers in the United States who had won awards for outstanding teaching of relevance. These workers found that in almost all cases the award-winning teachers had been adequately equipped and supplied with a range of technological resources and media such as audio systems, projectors, photographic resources and specialized equipment for biology. The implications are clear both for training and supply. In order to develop their full potential teachers need access to and must be effectively trained in the use (and production) of technological resources.

Training for organization of classroom and laboratory resources is changing to techniques of utilizing facilities of the media resource centres and service centres of the school and of the district

The development within the community of media resource centres, data banks (205), specialized training units and field centres, has encouraged the wider use of such resources by trainers in both pre-service and in-service programmes. Many examples of this type of interaction are discussed elsewhere in this chapter.

Training in the assessment of teaching is moving towards training in methods of evaluating in-service and pre-service programmes of teacher education

The involvement of students in the evaluation of teaching (156, 199) and of practising teachers in the evaluation of curricula (184, 250) are discussed elsewhere in this chapter.

Other trends in this area include the development of training programmes in methods of evaluating the effectiveness of whole systems of teacher education. The Educational Testing Service in the United States, for example, offers courses in the techniques of evaluating in-service activities (72, 307). On the whole, however, this area has been neglected. There is a great need for personnel who are qualified to evaluate the effectiveness of programmes of teacher education at both pre-service and in-service levels. In many countries, programmes to train these evaluators are urgently required.

TRENDS IN THE FORMS OF RETRAINING PROGRAMMES

In the past, most emphasis in retraining has been on the provision of special courses for biology teachers either as summer schools (Institutes); or weekend, evening or vacation courses (30, 61, 114, 115, 131, 165, 279, 293, 299, 309). More recently, the forms of in-service activity have diversified to include 'within-school' programmes; tours and visits; the use of teachers' centres and other devices. Courses remain, but the more traditional lecture course has been replaced by newer and more relevant forms. Rubin (241), Johnston (131), Finch (85), Harris, Bessent and McIntyre (107), Tibble (274) and Watkins (304), have all provided useful lists of possible ways to improve in-service courses and to seek alternative forms of in-service education.

Meyer has proposed some twenty criteria for developing national retraining systems for teachers (181). Of these criteria, the most significant is that they should meet the expressed needs of teachers. It is important, too, that teachers become involved in the planning and management of in-service programmes.

Retraining is most effective if it is planned on a national level as a total network system. Such an approach is especially important in countries with large populations such as India (31, 67, 103, 128, 183), Indonesia (22), Japan (28, 118, 143, 196), or Pakistan (124). This approach is also significant in countries developing biology programmes either from first principles or so as to reflect new national objectives, as in the case of many in the African region (163, 187, 188) such as Ethiopia (305) or Mauritius (9); or for countries such as Cyprus (37), Lebanon (190) or Papua New Guinea (32, 239).

In recent years, there has been a great diversification of the forms of in-service education for biology teachers and some examples are described below.

Courses

Attendance at courses is a well established form of retraining. There are many formats ranging from one-day events to extended one-year programmes (131). Content may range from the specific, as in courses provided by the University of Minnesota on the principles of biological rhythm (1), to the general such as in those offered by the Royal Danish School of Educational Studies on problem-solving and inquiry methods (240, 258). Many courses are designed to assist in some change such as the introduction of new curricula. Recent examples include courses offered by local Boards of Education in the Republic of Korea (177), the Indian Association of Teachers Educators (31, 267), the Curriculum Development Unit of Trinity College, Dublin (225), by the Ministry of Education in Finland (302), and by school authorities in Thailand (119, 120).

Some retraining courses are devised to upgrade the formal qualifications of biology teachers. Programmes offered by the University of Stellenbosch, South Africa (294) and by many National and State Departments of Education such as the Department of Education in Hawaii (109) are examples.

Courses have been devised to cater for retraining in new approaches to subject matter. Examples include the courses in environmental education offered by the Institute of Education in Mauritius (9) and more general programmes designed to upgrade understanding of biological concepts such as those offered by the Norwegian Ministry of Education (212), the London Institute of Education (165, 293) and the Institute of Biology in the United Kingdom (106); the Natal Education Department, South Africa (300), and by the Institutes for Teacher Training in the Soviet Union (249). Some institutions provide more general programmes fusing both biological content and pedagogy. The Summer Institutes of the National Science Foundation in the United States (114, 299), the All-India Indo-British Summer Institutes (309), the programmes arranged by Cape Coast University in Ghana (211), and by the Ministry of Education in Venezuala (18), and the international programmes held annually in Buenos Aires on behalf of the Organization of American States (100) are all recent examples. Some courses are devised to train in specific skills such as the use of new science equipment (103) or audio-visual technology (200, 201, 238).

Motivation to attend optional courses remains a significant problem. In Italy, school authorities make it clear they expect teachers to be up-to-date in the preparation of specific subject matter. Voluntary courses of up to ten days each are provided for this purpose throughout the school year (276). The Department of Education on Nova Scotia, Canada, has offered special industrial inducements to teachers to participate in innovative programmes (84, 209). A recent trend is towards the minicourse format. With its minimum time span and a flexible unit-type programme, it represents a partial solution to the problem of motivation since it implies only a minimum commitment at any one time to retraining, yet usually encourages continued involvement (180).

Workshops for specific purposes

Retraining programmes are most successful if they involve teachers in activities - an approach consisting of merely providing lecture programmes has proved to be relatively unsuccessful (85, 131, 181, 304). Workshops held in evenings, at weekends or during vacations, where teachers work together to produce equipment, learning resources, tests, programmes and other materials are especially successful in developing skills.

The workshops held by biology study groups in African countries - Kenya, Malawi and Tanzania for example - to produce textbooks, test materials, statements of objectives and curriculum guides for new biology courses are exemplars of this method (185, 188, 287). Workshops held by the Newark School District in the United States to train teachers to produce audio-tutorials (26) and the minicourses at Macquarie University in Australia on production of slides, overhead projectuals and audio programmes (180), are cases of workshops designed to train teachers in A-V production.

Conferences

Conferences sponsored by employing authorities, science groups, teachers' centres, science teachers' associations and other community groups are an especially effective form of retraining (131). They bring together groups of biology teachers to discuss a particular topic, to plan action or to exchange information. They are effective at local, national and international levels.

In the Philippines, the Annual Conferences of the Biology Teachers Associations held since 1966 have reviewed trends in curricula and teaching technique (2). An example of similar conferences at regional level is the very successful series sponsored by the Asian Association of Biological Education held in turn in various countries of Asia (4). There are many examples of national planning conferences, such as the meeting sponsored in the United States in 1970 by the Commission on Undergraduate Education in the Biological Sciences to plan programmes for the pre-service preparation of college biology teachers (47).

Useful world-wide conferences on teacher education are mounted from time to time by international agencies such as Unesco (284, 285, 286) and, for countries of the British Commonwealth, by the Commonwealth Secretariat (48).

Exchanges and secondments

Exchanges of staff within and between school systems locally, nationally or internationally, including secondments and intern programmes, are becoming increasingly popular as forms of retraining. They enable teachers to learn about alternative curricula and methods, to obtain new resources and to develop new attitudes and values. Secondments to organizations other than schools, such as libraries, museums, zoos, curriculum units, and industrial organizations, are also very broadening forms of retraining and are increasing in frequency.

In Australia, recommendations have been made at the national level to provide practising teachers with an opportunity to work on secondment for a period in commerce and industry (314). The State of Hawaii in USA sponsors exchange of staff between schools within the state (from island to island) and also arrange interstate exchanges with mainland schools (109) - an especially important programme for a relatively isolated community.

Internship or apprenticeship programmes are now increasing. A national conference in Kenya held in 1968 suggested that retraining courses designed to upgrade the qualifications of teachers should include at least two terms of supervised apprenticeship teaching in schools (48).

Visits and comparative education tours

Organized and structured visits to various schools and institutions and group tours to survey the educational systems of other countries are recognized and useful forms of retraining. They provide rapid access to a range of alternative procedures and resources and are effective in stimulating innovation (181).

The school system of Jefferson County, Kentucky, has sponsored a series of afternoon visits to schools in the district. Displays of learning materials, biological specimens and pupils' work from the basis for an organized exchange of information (315: p. 9-12). The State of Hawaii, in addition to the exchange programme already described, encourages educational travel. Approved programmes may count for credit towards advanced qualifications in teaching (109).

In the United Kingdom, annual comparative education tours organized by the Institute of Education take pre-service and in-service groups to European countries such as Austria, Denmark, France, the Netherlands, Italy, and the Soviet Union (165).

Study leave and individual study programme

Sabbatical or study leave for teachers is a valuable and important form of retraining. In addition, supervised study programmes for teachers within schools have considerable value.

In New South Wales (Australia) study leave for teachers is sponsored for international visits

of up to one month. Teachers can attend conferences, arrange visits or undertake study at specified institutes (91). The State of Hawaii arranges more extended forms of sabbatical leave. Applicants must state purpose of leave, specific objectives, activities planned and proposed method of evaluating the effectiveness of the programme (109).

Consultancies

In recent years there has been an increasing tendency for school systems to employ consultants to visit schools to advise on curriculum, evaluation and teaching method (92). A recent survey by Maben of representative elementary schools in the United States showed that about 50 per cent of the schools in that country had access to some form of consultancy or supervisory service (169). A specific example in the United States is provided by the Delaware school system which employs field agents to visit schools to help solve teaching problems (25, 102, 166, 237).

Most school systems in Australia employ consultants. In New South Wales, some are attached to local in-service committees and help these committees determine needs (91). The environmental consultants employed in Queensland have been discussed previously (41). In South Australia, a panel of biology educators visits schools to assist with in-service activities (132, 167, 255). A programme has been mounted by the State College of Victoria at Hawthorn to send consultants to schools to provide training in marine biology (164).

The school authorities in Peru have developed a decentralized system of consultancy. Trained consultants are appointed to a large district school and help the staff of that school provide programmes for other schools in the district. Consultants also regularly attend special training courses provided by the Ministry of Education (230, 231).

The National Board of Education in Sweden employs consultants to help plan retraining programmes, produce training materials and visit schools to organize study programmes for teachers (204).

In some countries, consultants are more usually associated with specific curriculum projects (286) or with in-service institutes such as the Institute of Education in Kenya (269). In Ghana, the chairman of the Biology Study Panel of the Ministry of Education visits schools on request (211).

Production and dissemination of training kits

Training manuals, teachers' guides and, more recently, multi-media training kits, have been widely used in retraining programmes. Some are designed to be used by individuals, and most teachers' guides associated with textbooks and new curricula take that form - examples are the teachers' manuals issued by BSCS (99) and by the Secondary School Science Project in East Africa (187, 188). Others are designed to be used by groups, introduced either by a visiting group leader or by one member of the group who acts as a leader and is helped by an instructors' manual. Examples of the latter approach are the multi-media modules developed in Australia by the New South Wales Science Syllabus Committee for the School Certificate (207). In Western Australia, training kits involving tapes, slides and printed materials are organized into training units of less than twenty minutes on specific skills and are sent to schools. They can be worked by individual teachers or groups either in school or at home (14). The Department of Education in Papua New Guinea has issued an 'In-Service Professional Development Handbook' to inform teachers of in-service programmes (32).

Most school systems and Science Teachers Associations issue journals and other publications which provide some element of retraining and many have organized in-service libraries, sometimes with a book mailing service (5, 31, 91, 132, 149, 200, 201, 215, 238, 243, 291,

308, 313).

Displays and exhibitions

Displays and exhibitions of new learning resources and materials, of biological specimens, science apparatus and audio-visual equipment are useful in-service devices. They may involve materials produced by curriculum centres or commercial firms or made by teachers and pupils.

Many such exhibitions are mounted in association with conferences, workshops or other in-service activities. They may be sponsored by an employing authority by teachers' associations, teachers' centres, curriculum developers, commercial firms, individual schools or by independent groups of teachers. Many effective exhibitions are developed by institutions in association with an 'education week' or an 'open day' such as a science fair or school science research competition.

A recent trend has been the development of mobile displays such as the media mobiles of the Tasmanian Department of Education in Australia. Equipped and staffed vans visit schools, and programmes are mounted to train staff in using new audio-visual equipment (88). Loan collections of specimens and other resources are also frequently available from museums, libraries, teachers' centres and other in-service institutions.

Displays and exhibitions provide an opportunity for teachers to rapidly survey recent developments in a particular area and encourage experiment and innovation in teaching method.

Involvement in research and development

One of the most powerful and effective ways of retraining teachers is to involve them in aspects of research and development. They can participate in the development of new curricula; in testing new resources and methods; in experimenting with alternative forms of assessment and in undertaking certain types of basic educational research. Such involvement encourages teachers to innovate, to explore alternatives and generally to upgrade their understanding of both biology and pedagogy.

Many examples of teachers working with curriculum teams in development testing and evaluation have already been described (see especially 15, 29, 33, 99, 117, 176, 184, 187, 277, 286). Other examples include the work done by teachers in Kenya to develop a new Advanced Level Syllabus in Biology (269); participation by teachers in the Caribbean Regional Science Project (295, 311); the teacher team at present designing a new science curriculum for Botswana, Lesotho and Swaziland (175); and the release of teachers from school time to help with the 'Canadian Environmental Concerns' curriculum for Manitoba (306).

The trend to involve teachers in developmental research is increasing because curriculum development is now more decentralized (30, 61, 91, 279, 304) and because, in developed countries such as the United States, fewer beginning teachers are being hired, implying the need to introduce new curricula through in-service rather than pre-service programmes (125).

Development of new in-service institutions

Non-school

In the past decade there has been, in most countries, a rapid growth and diversification of new-style institutions for the retraining of teachers. These include teachers' centres; environmental and field centres; special retraining units in museums, in botanical and zoological gardens and in libraries; and the establishment of special staff colleges.

One of the most rapidly expanding of these new systems is the teachers' centre movement. The Australian Department of Education has set up Education Centres throughout the country (141) and centres have also been established by universities (182) and departments of education in each Australian state (91, 229). The teachers' centres in the United Kingdom are probably the best known and the best established and have a long record of successful intervention in the improvement of teaching competence through provision of resources, training courses, consultancies, conferences and other activities (56, 151, 293). In some countries, national centres have taken a leading role in the retraining of teachers. The National Council of Educational Research and Training in New Delhi (67, 128) and the University of the Philippines Science Education Centre (116, 266) are outstanding examples. Howe has prepared a useful comparative survey of teachers' centres in Australia, Scandinavia and the United Kingdom (123).

The science education centres in Japan are of special interest. Each of the forty-seven prefectures has its "Science Centre" and, on average, 10 per cent of the science teachers of both junior and senior high school are involved in in-service seminars each year. Training courses of several days' duration are provided and these may involve field trips. Teachers are released from school time to attend and the courses are voluntary (28, 196). These Japanese centres have been described in some detail in a comprehensive report on the Training of Science Teachers in Japan compiled in 1970 by the Japanese National Commission for Unesco (129: p. 164-190).

There is a trend towards the development of international centres, some sponsored by agencies such as Unesco (288) and others by co-operating groups from neighbouring countries. An especially interesting example is the Regional Centre for Education in Science and Mathematics (RCESAM) in Malaysia, sponsored by the Southeast Asian Ministers of Education Organization. RCESAM undertakes curriculum development and has a continuing education programme for biology teachers of the region (220).

Community science centres such as the Lawrence Hall of Science at Berkeley, California (77) and the education units of museums, zoos and gardens (91) are playing a key role in retraining by giving on-the-job experience and by providing courses for teachers. Information clearing-houses such as the ERIC Science Centres at Ohio State University and the University of Maryland; the Science-Math Resource Centre at Dover, Delaware (252), and centres established by the Kentucky Department of Education (145), are interesting examples of information units that provide some retraining.

Field studies centres and environmental centres have also provided special retraining programmes. The field study centres in the United Kingdom and the United States are well known in this regard and many other countries have established similar centres with retraining as one of their objectives. Related to these are the agricultural extension services that are found in many countries and which help biology teachers with advice and information (139).

John Goodlad defines centres such as those described above as 'pedagogical service stations' which assure the development of those specific skills which teachers want to perfect (96: p. 257).

Another type of development is the staff college or retraining institute especially set up, usually by the employing authority, to systematically retrain teachers. There are a number of examples but one of special interest is the In-Service College proposed by the Department of Education in Papau New Guinea which will introduce a 'credits' scheme for all teachers attending organized programmes (32).

Within school

Ultimately, the best retraining must occur within the school itself and organized programmes for within-school development are rapidly increasing. The provision of 'release time' to attend in-service activities both in the school and beyond is now well established and the use of within-

school training modules has already been considered as have self-evaluation profiles such as those provided by the National Science Association in the United States.

Other ways retraining is organized within schools include: provision of specially appointed staff to organize in-service activities (57, 75, 249); special programmes for probationary or neophyte teachers (37, 83, 203); schemes for the ordinary staff to train new teachers (88); and provision for special study days (as in Sweden) where all teaching stops and retraining programmes are introduced (204).

An interesting approach has been adopted in the United States by the University of Massachusetts. The University has sponsored retraining programmes within schools by involving the biology teachers in a within-school-team that interacts with the training facilities of the community - the model focuses on environmental problems as a unifying theme and draws on all relevant training resources (268).

Training programmes for in-service personnel

The need to provide special training programmes for course leaders, consultants, supervisors and other involved in the continuing education of teachers has only recently been appreciated. The special skills of in-service leadership and management are, however, subtle and complex and in-service personnel benefit by training.

The National Board of Education in Sweden trains its in-service consultants in a two-week course followed by regular information conferences (204). In Australia, the Centre for Advancement of Teaching at Macquarie University provides minicourses for teachers in the leadership skills necessary for in-service work (180) and in the United Kingdom, Digby Stuart College provides summer vacation courses for teacher-tutors who have responsibility for the supervision of trainees and probationary teachers in schools (65). Ain Shams University, Arab Republic of Egypt, each year sends a recently qualified scientist to the University of Wisconsin, United States, for seven months for training in science education. The objective is to establish a link between scientists and educationalists so that both can effectively participate in programmes of in-service training (68). In India, the State Institute of Science at Sasthamangalam, provides special training courses for biology teachers who, in turn, conduct a series of in-service courses for other biology teachers. These courses are held at the Institute and range from thirty to ten days during school time (70). These and similar programmes are the beginning of a trend that must accelerate if continuing education programmes are to be successfully upgraded.

Research into retraining

There is a great need for research into the forms and effectiveness of programmes of continuing education for biology teachers. Some research has been undertaken into favoured methods and forms of in-service activity (241, 304). In Australia, research is being undertaken to evaluate the effectiveness of the Australian adaptation of the STEP programme (171). In Jordan, Billeh has compared the relative effectiveness of pre-service and in-service programmes of science teacher preparation and has concluded that in that country in-service methods are more effective (21). There is, however, very little evidence concerning the effectiveness of overall systems of retraining, the improvement of teaching competence, and the quality of pupils' learning. This general area of research into in-service education will most certainly receive increasing attention in the next decade.

CONCLUSIONS AND RECOMMENDATIONS

The objectives of biological teaching in schools have broadened so as to stress satisfaction of personal, social and national needs. School biology teachers, therefore, are now generally seen to require knowledge, understanding and skills in both biology and education. This change in emphasis implies the need for a balance and integration between biology and pedagogy in any programme of teacher education. There is a world trend towards the concurrent, rather than the consecutive model of training, and this has come about partly in response to the need for a closer link between biological and professional teaching aspects of training. While the concurrent model is gaining in favour, reorganization of consecutive programmes also continues and it is not yet clear which model will eventually prove the more effective. It is therefore *recommended* that a programme be established in order to investigate the relative effectiveness of the consecutive and concurrent methods of teacher preparation.

In pre-service programmes, the integration of biology, biological didatics (teaching methods) and pedagogy can be achieved in a number of ways. Perhaps the ideal would be to have especially trained staff so that these aspects can be covered by the one person. A compromise would be to develop genuine team teaching, with the team members coming from the academic discipline and the education disciplines, team teaching to mean at least close co-operation in the same teaching-learning environment to achieve agreed objectives. Where neither of the above is possible, strong links between the educational and biological strands could be encouraged by such devices as co-examining on the basis of agreed aims and by sharing information between departments through joint steering committees and other similar bodies. Whatever the model of training or the level at which the teacher functions, however, pre-service courses should include both the discipline and didactics of biology.

With regard to biology in the primary school (see the chapter on 'Trends in the biological component of education at the primary and junior secondary level') very different degrees of emphasis are given to its place in the primary curriculum from country to country. This diversity of emphasis is reflected in programmes of teacher training. In different countries there is variation in the length of training for primary teaching as a whole and there is especially wide variation in the time given to biology, both academic and didactic (teaching methods), during training. While most teacher educators seem to agree that, at the primary level of education, general teachers are preferable to subject specialists, it seems desirable that all primary teachers in training should study biology and biological didactics. The amount and nature of the subject matter would necessarily differ in different countries as it should be designed to fit the needs of a child in the changing society of each country. It seems that while the contribution of biology to primary education is unquestionable, in most countries its present status is unsatisfactory. It is therefore *recommended that* Unesco organize a conference to examine the nature and place of science in the primary school, including a consideration of the facilitation of change at that level and of the development of appropriate programmes of teacher education.

With regard to the continuing or life-long education of biology teachers there is, in most countries, a significant lack of co-ordination between pre-service and in-service cycles. One trend noted is a growing involvement of pre-service trainers in in-service activities and this is to be commended. There is, however, a need to review the overall patterns of teacher education in many countries so as to ensure development of coherent, balanced, yet widely diverse opportunities for qualified biology teachers to seek further training in any specific or general aspect of their profession. While it must be the responsibility of the individual teacher to select the elements of his continuing education, there remains the problem of who should be responsible for ensuring that all necessary elements are available and accessible. This is an especially important problem in countries in which there is a multiplicity of groups and institutions offering programmes on specific aspects of the profession. This issue remains open as different solutions are likely to be found in different countries. There are, however, trends towards involvement of the

whole community in the continuing education of teachers. This implies that the community must be aware that in-service training is an essential part of the professional development of teachers. It is therefore *recommended that* international and national agencies mount programmes of adult education to inform the general community of its needs and responsibilities in regard to continuing education, not only of teachers but of all citizens.

Related to the question of responsibility for providing coherent programmes of continuing education is the issue of how overall systems of training can adapt to changing needs of society. A central aspect is the general problem of overcoming barriers to meaningful change and innovation. One obvious way to facilitate innovation would be to disseminate more widely than occurs at present, information on successful innovations and how they have been achieved. It is therefore *recommended that* Unesco and IUBS promote dissemination of information about successful innovations in biology teacher education by appropriate means and as widely as possible. More and better communication between all categories of institutions and educators as well as between nations is required.

In rapidly developing systems, there remains, however, the possibility of change for its own sake and in teacher education there is an inadequate record of critical and meaningful self-evaluation of innovative programmes. Part of the explanation lies perhaps in the absence of valid and reliable methodologies. It is therefore *recommended that* appropriate research programmes be initiated in order to develop technologies for the evaluation of innovations in the pre-service and in-service training of biology teachers.

Even more difficult problems emerge in situations requiring an overall evaluation of the effectiveness of a total training and retraining programme for any given school system. In all programmes of teacher education, the ultimate objective is to bring about favourable changes in pupils by improving the competency of teachers. It is, however, difficult to identify and evaluate the numerous factors that change the behaviour of pupils. Even if teachers change their behaviour as a result of training, it is very hard to establish that these changes alone have caused a change in the behaviour of pupils. The answer perhaps lies in planning the evaluation of training and retraining as a sub-system of the educational system as a whole. As yet little attempt has been made to develop appropriate methodologies to solve this problem and it may well be a central issue in the next decade. It is therefore *recommended that* Unesco sponsor research and development to find suitable models for the overall evaluation of the effectiveness of (life long) teacher education programmes for given school systems.

An area of concern in many countries appears to be the absence of systematic training programmes for teacher educators. Traditionally teachers' colleges and other teacher education institutions have been staffed by ex-school teachers of excellence, in the expectation that these people in turn can transmit their teaching skills to others. Quite frequently, however, these ex-teachers are unable to make a successful transition from teaching school pupils to training young adults. There is a general need for retraining at this level. It is therefore *recommended that* Unesco disseminate information on the advantages of, and methods for, establishing staff improvement programmes within institutions of teacher education.

Finally there is the issue of motivating teachers to recognize their responsibility to be involved in continuing education. Teachers may of course require help in identifying their specific needs and this may well be the responsibility of curriculum developers or employers. But motivation to be active in self-education is a more difficult matter. The trend towards retraining a whole school staff through dynamic within-school programmes might well be the correct approach. Artificial inducements such as systems of credit points for promotion are usually not the answer as these imply a terminal goal in what is essentially an open-ended endeavour. No specific recommendations can be made, however, and motivation to accept continuous retraining must be encouraged by means appropriate and acceptable in each country.

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   A useful discussion of the problems of educating lecturing staff of institutions teaching biology at the college level. Case studies of staff training programmes in the colleges of the United States are described. While the account is not limited to teacher education, most of the suggestions and case studies are relevant to the staff of teacher education institutions.
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   This report includes a comprehensive statement of the desirable qualities of school biology teachers and reviews aspects of objectives, organization, strategies and assessment schemes of programmes for training secondary school biology teachers. Highly recommended as a useful practical guide.
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8. Rubin, L.J. (ed.). *Improving in-service education: proposals and procedures for change.* Boston; Allyn and Bacon, 1973.
   A collection of writings on the general problem of the continuing education of teachers. Overviews provided by the editor in chapters 11 and 12 are especially valuable. This book is a basic reference for those concerned with the in-service education of teachers of all subjects at all levels of the school system. It is highly recommended.
9. Sutton, C.R.; Haysom, J.T. (eds.). *Science teacher education Project.* Maidenhead; McGraw-Hill, 1974.
   All books in this series are relevant to the education of biology teachers. The titles are:
   Activities and Experiences
   The Art of the Science Teacher
   Film Review
   Meadowbank School
   Theory into Practice
   Through the Eyes of the Pupil

Innovation in Teacher Education *Readings in Science Education*

This remarkable series of manuals provides a comprehensive practical guide for those concerned with the training of science teachers. Almost all the material is relevant to biology teacher education. While the orientation is towards teacher education in the United Kingdom, much should be readily adaptable for use by other educational systems. This is essential reading for science teacher educators.

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    While all chapters of this report contain much material of relevance to the training of biology teachers, the chapter by Perlberg on 'Educational Technology in the Professional Training of Science Teachers' is of special interest (p. 221-239). This provides a rationale for the use of educational technology in programmes of science teacher education and includes helpful practical descriptions of relevant technologies such as modular teaching; simulations, including microteaching; and of audio-tutorials and other types of multi-media programmes.

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Trends and problems in designing introductory university-level biology courses

INTRODUCTION

The expression 'introductory or basic university courses' has diverse meanings in different countries and may even have numerous meanings within the same country.

The organization of the university system varies greatly and includes private, governmental, religious and secular institutions that in themselves may be new and modern or old and highly traditional. The biology courses offered reflect this variety. The publication *The context of biological education–The case for change* prepared by the Commission of Undergraduate Education in the Biological Sciences (1972) presents a classification for introductory courses in the United States which includes the following:

1. Programmes which prepare students for graduate studies in biological science;
2. Programmes for teacher preparation (secondary or two-year college);
3. Pre-professional programmes (pre-medical, pre-dental, biotechnical, etc.);
4. Programmes in resource management and related sciences (agriculture, soil sciences, agronomy, forestry, wildlife management, etc.);
5. Good undergraduate programmes for non-majors.

This classification, even if the nomenclature is not everywhere the same, includes the most frequent types of courses offered throughout the world whether they present general education or professional training characteristics. In Latin America, despite some very controversial attempts to install basic courses of a general education nature, such courses, from the first year onward, are concerned, as a rule, with training students to be professionals.

It was recommended by the biologists participating in the International Congress of Biology Education that courses in biology should be available for professional students, technologists and

liberal arts students.

Another possible interpretation of the term 'introductory courses' is that of secondary courses prepared for students who are interested in biology. The best known of these are the three versions of *Second Level* BSCS Courses and the *Advanced Level* Nuffield Biology Project. In both cases the authors' intentions were not to prepare students for university-level studies but to elaborate advanced courses for the secondary level. As Young (1970) says:

> 'In any case, the emphasis on the requirements of those who will not go to a university or other institute of higher education is increasing and will probably continue to do so, and the need is for courses which are satisfying and intellectually exciting in themselves – not for courses which are simply passports to further study.'

Even though these projects were not prepared for students wishing to continue their studies at university level, they were widely used for this purpose and were even used as introductory courses in universities.

The term 'introductory course' will be used here to refer to biology courses given during the first years of university study and the content of which is selected for biology as well as for non-biology majors.

Since the sixties, science teaching has undergone many changes. The secondary level has been most affected by this renovating movement which produced numerous curriculum projects of considerable impact (see the chapter on 'The development and design of new courses in secondary biological education'). Since it is impossible to touch one part of the educational system without affecting the others, tertiary teaching was accordingly influenced by the winds of change, although the effects at this level were rather mild. On the other hand, movements within the university system have brought about greater reflexion and subsequent changes in the teaching organization at this level. These movements are active even today in university teaching.

The expansion of the educational system and growing aspirations for education have provoked a change in the population entering the university. The growing role of student participation in discussions of university policy in some countries together with technological developments were, according to Trent and Cohen (1975), the prevailing forces that changed the form and content of university education during the sixties. At the present time, questioning of the aims and role of university education continues. University education is placed between autonomous development and integration into the educational system, between quality and quantity, between teaching and research and between general education and professional preparation. When precise answers are needed concerning objectives and aims in the various sectors of university education, as in the teaching of science and biology, these dilemmas generate other questions: Is the university's role to provide a liberal education and give all students an opportunity to understand the processes and products of science? Is it possible to offer remedial courses to make up for the deficiencies of science education at high-school level? Is the university's only role to satisfy the requirements for the various professions? The choices made between these alternatives determine the kind of courses that a college will offer and the organization of the curriculum for introductory biology courses.

The hopes that were placed in science as an element of transformation in the life of the human species have given way to a more moderate, not to say sceptical and cynical attitude about the beneficial role of scientific development. Though we may regret this decline in interest, which is derived from a general atmosphere of pessimism, it is healthy to think once again about our positions and functions as participants in the educational process when planning biology introductory courses.

CURRICULUM DECISIONS

Even though the various sectors responsible for teaching organization continue to discuss the real objectives of introductory biology course teaching in universities, final decisions about the

courses and their structure are still based upon the personal opinions of the professors.

Each professor is lord of his own small fief, basing his decisions on what and how to teach according to his personal convictions, interests and tastes. Very little consideration is given to students' educational background and motivation. Moore (1965) studied 32 colleges, covering a wide range of types of introductory biology programmes, and found that there is a great variation of content among them. The characteristics of the course depend on decisions reflecting the interests of the instructor.

It is generally agreed that there is a need for group collaboration in course planning which is based upon information about students' interests, background, requirements, etc., but there are far too few publications that mention this kind of problem. It was for this reason that the Second Interamerican Conference on the Teaching of Biology recommended that 'in the elaboration of curricula and programs, at any level of teaching, special emphasis must be given to the study of man in his physical and psychological aspects and his relationship to the physical and social environment (OEA, 1973)'.

COURSE CONTENT

Decisions about course content are based on the nature of what should be taught, the sequence in which the subjects should be organized and the integration of the various areas of the curriculum.

Because of their structure, many universities and institutions of higher learning are bound to an obsolete organization which impedes content substitution, the introduction of new courses and the creation of new departments. The possibility of innovation is drastically limited. In many cases, even though the teachers of a given college agree on the necessity for curriculum changes, the difficulties in the reorganization of course material that could lead to the alteration of an already established structure hinder the implementation of the project. This is one of the main reasons why fragmentary biology courses are still being given, even though the need to present the first-year student with a global view of the biological phenomena has long been recognized. Students who specialize in such other fields as zoology, botany, micro-biology, etc., should be introduced to the fundamental processes and basic principles of biology, so as to obtain a panoramic view of their own field.

Because of a long-standing tradition, most of the introductory biology courses are still divided into zoology and botany, further subdivided into morphology, physiology, systematics, etc. When a student decides to major in the biological sciences, he or she will enrol in several courses simultaneously – e.g., vertebrata, plant morphology, cytology or any equivalent combination. There are even examples of a strict division between animal and plant ecology. What happens is that the student sees only parts of a puzzle that sometimes are never assembled to form a complete picture.

Several experiences, however, such as that conducted at the University of Malaya, show the practicality of such efforts. Faculty members were unhappy with the classical botany/zoology division of their courses because of the elaboration of identical courses that such a division imposes, because of subject overlapping and the waste of resources and time by professors and students alike. Scientific research was also handicapped since each department carried out its own work independently of the other. As a result, the needs of the nation as a whole were sacrificed because of a faulty structure. An attempt to change the prevailing situation was made on 1 April 1967 with the founding of the School of Biological Sciences which resulted from the fusion of the Departments of Botany and Zoology. According to Prakash (1969), this change

> 'gave different dimensions, meaning and impetus not only by permitting better utilization of existing resources but also by a more effective co-ordination of teaching and research in the disciplines of biology. The greatest advantage of the course in Biology now being taught at the University of Malaya lies in the intrinsically basic approach to biology. Constant

> vigilance is kept; time allocation, course materials, etc., are modified and improved as needed in accordance with the availability of staff and laboratory space. The approach of the newer course thus introduced in Biology is one which emphasizes the phenomena that underlie all living systems from the sub-cellular to the organismic and population levels. In conjunction with this broader emphasis, the present approach embodies the discussion of the unifying principles of biology, wherein details of specific examples are introduced only to support the principles. Discussions of the principles to the exclusion of specific examples is indeed avoided because it is impossible to talk about principles without discussing details'.

Besides the advantages already mentioned in respect of course content and the decision as to what exactly should be taught, the new division of responsibilities brought about savings in terms of time and space, and all faculty members showed a definite improvement in their work. The pleas for better working conditions and the subsequent fusion of the two sciences greatly benefited and strengthened the institution.

This kind of strategy can be successful in some schools, but in others the presence of an archaic structure can be an obstacle to the solution of existing problems. Large universities generally find it more difficult to undertake such reforms because of their size and the complexity of their administration. This phenomenon is very evident in Latin American universities.

Even when structural modifications can be accomplished, it is still essential to change professors' attitudes so that they can see things in a new light and organize their courses and teaching methods accordingly. Attaching new labels to old courses does not always mean an accompanying change in their nature. An extensive and thorough analysis of the topics and elements of each course must be made to ensure that university students will receive, from the outset, some knowledge of modern biology, a science which has basic principles, which will allow the formation of a coherent complex of ideas instead of the hazy vision composed of scattered and unrelated facts which they too often receive.

In a word, the content of introductory biology courses evolved from a classical botany-zoology programme emphasizing morphological and taxonomic aspects *to* general biology courses, including cell biology, developmental biology, genetics, etc. CUEBS (Commission on Undergraduate Education in the Biological Sciences) conducted a study to analyse the different needs *for* biology programmes – agriculture, health sciences or graduate study in biology. The final selection included Purdue University, Stanford University, North Carolina State University at Raleigh, and Dartmont College. The topics common to the four institutions are shown in the the following list:

	Units of time
Taxonomy	0.0
Ecology	0.7
Evolution	1.1
Growth	1.3
Development	1.4

	Units of time
Physiology, general	2.2
Reproduction	2.5
Morphology	2.7
Genetics	12.1
Cell Biology	15.6

One of the final recommendations related to the central curriculum (core curricula) of the CUEBS publication, *Content of core curricula in Biology* (1967 was that consideration be given to:

> 'what are now recognized to be fundamental biological concepts. These include, at all levels of biological complexity: structure- function relationships; growth and development; the nature of hereditary transmission; the molecular basis of energetics; synthesis and metabolic control; the relationship of organisms to one another and to their environment; and the behaviour of populations in space and time, especially in reference to evolution'.

The list of principles suggested by the authors of this article may be discussed and modified

according to the opinions of specialists in each particular college, in terms of scientific evolution and progress and according to student motivation, but in general terms it represents the central nucleus of any modern biology course as supported by the International Congress of Biology Education. Care must be taken that introductory courses do not evolve in such a way that the basic objective of the study of living things is lost.

If the transition from fragmented biology courses to those forming part of a unified curriculum is difficult and productive of difficulties, the new tendency – science courses that integrate subjects such as biology, physics and chemistry – also demands that professors undergo a change in attitude and that the various science departments of the university elaborate a new teaching organization.

The general trend in science teaching during the seventies shows a growing preoccupation with social problems and their relation to scientific and technological development. The same concern is found at all educational levels including the university. Many of the articles in the last two volumes (III and IV) of the *Journal of College Science Teaching* discuss the social implications of biology and science teaching. The high proportion of articles dealing with this problem clearly indicates the direction in which teaching is heading.

The need to consider ecological problems such as pollution, the population explosion and the energy crisis is a constant in today's biology and general science introductory courses for majors and non-majors alike. The titles and composition of this type of course vary widely but they have a general factor in common: an attempt to be relevant and humanistic and to consider social problems. But a problem emerges – are biology teachers prepared to discuss social problems? They are expected to be as competent as any other intellectually mature person to discuss with their students problems of general concern. 'As an outgrowth of widespread student unrest on college campuses several years ago, science faculty scramble about trying to be more relevant' (Aronstein and Beam, 1974). A course was organized by the General Science Department of the State University College at Buffalo to meet the demand for relevance, humanism and scientific literacy. The explosive aspiration to knowledge and the impact of science on modern life were considered in determining the objectives of the introductory course. Students were confronted with problems that should be solved humanistically so as to help develop their capacity to make decisions and to use scientific literature. Professors and students jointly chose the topics of the problems to be solved and these included such themes as pollution, drugs, space exploration, oceanic exploration, the use of natural resources, etc.

Another example of this tendency is the Contemporary Science Course given at the Rochester Institute of Technology (White, 1974). The basic themes are energy, science in action, and man and science. The courses are taught jointly by the Departments of Physics, Chemistry and Biology. Three hundred and sixty students are enrolled in the course and attend three classes a week plus a weekly discussion session for groups of 25 students. Mimeographed texts are distributed and replace the traditional textbook and laboratory manual. Discussions include theories, scientific concepts and aspects of public interest.

It was felt by the group discussing the problem at the International Congress of Biological Education that biology should be taught as a separate subject and at the moment general integrated science courses are not recommended.

However, the social implications of biology and the major problems of the present day – food, pollution, genetic engineering, population explosion, etc. should be included in biology introductory courses. Several introductory courses are already doing so. For example, the topics covered by the 'General Biology – audio-tutorial – independent study' (Gaddis, 1972) developed at the University of Arizona are: evolution of man; ecosystem concept; habitat concept; human physiology and disease; reproduction; regulation; population ecology. The Unit Bank Biology project prepared at the University of Kiel (Schaefer, 1972) structures biology teaching from secondary school to university introductory courses along guide-lines such as anthropology, ecology and processes of learning. Several other examples can be found in the literature (Dolphin, 1973;

Dowdeswell, 1974; Raw, 1975).

A slightly different way of facing the same problem is to include ecology courses in university curricula, beginning in the freshman year. This is done at the University of Bath in the United Kingdom (Dowdeswell and Potter, 1974). This course tries to integrate botanical, zoological and microbiological aspects around three basic themes: the spatial distribution of organisms; the flow of energy in ecosystems and the gene as an element in population continuity. The justification for this option resides in the fact that:

> 'Ecology should occupy an important part in any introductory biology course, not only as a subject in its own right, but also because of its relevance to other subject areas, such as physiology, behaviour and genetics, and to contemporary problems such as conservation and pollution' (Dowdeswell and Potter, 1974).

The students meet one day a week during ten weeks with a two-hour lecture/discussion session in the morning and a laboratory period of two-and-a-half hours in the afternoon. The objectives of the course are that the students should become familiar with basic ecological principles, and learn to use scientific literature and to develop ability in data collection used in ecological studies.

At the Federal University of São Carlos in Brazil, the introductory biology course is also organized around the basic theme of ecology. A case study of a lake situated on campus serves as the centre for curriculum planning. Starting from this basic problem, the students analyse the relationship between the lake and the surrounding terrestrial ecosystems. The class is divided into groups, each studying a different aspect of the same research project. During four months, students have 30 hours of expositive/discussion classes and 90 hours of field and laboratory work. The two instructors in charge of the 45 students believe that the approach maintains a high level motivation, improves students' ability to synthetize by starting their projects from scattered data obtained from several sources, and encourages them to use a more integrated approach to science. (Tundisi, 1975). In introductory biology courses, one is therefore confronted with a new challenge: that of integrating biology as well as integrating scientific knowledge and discussing its social implications so that they become meaningful and relevant to university students.

STUDENTS

The desire for a university education is no longer restricted to a particular social class. Even though many youths today feel that their expectations of a better way of life cannot be met by the university, they continue seeking admittance. As a result, there has been an increase in both the number of applicants and in the number of colleges and universities to meet this demand. The selection system has had to be improved and this has caused controversy and discussion within the academic community because of the social, economic and political consequences.

In Brazil, some institutions in charge of preparing university entrance examinations have become important centres for educational research. The Carlos Chagas Foundation, established in 1965 to prepare entrance examinations for biomedical colleges in the state of São Paulo, annually marks the examinations of 20,000 students competing for the 1,500 openings at the universities. A number of similar institutions have recently been founded to prepare college boards for the humanities and physical and mathematical sciences in São Paulo and other Brazilian states. It is easy to imagine the repercussions of this on the whole educational system since the taking of entrance examinations is the norm in secondary schools. The college boards also influence teaching at the university level since the student body is selected and defined by them.

The same situation exists in the United States where institutions such as the Educational Science Service also have a tremendous influence in curriculum planning at both secondary and university levels. According to Kirst and Walker

> 'Over a million students take the College Boards and several hundred institutions require it. Consequently, local schools do not have a choice as to whether they shall offer the dozen

subjects covered by the achievement exams of the College Boards. These tests do not entirely determine the detailed content of the curriculum but they do limit what teachers can spend time doing.'

Birnbaum (1973) referring to the importance of university entrance examinations writes:

'what occurs annually at the time of college entrance examinations can be found in few countries outside of Japan. Students may spend long periods cramming for entrance to particular universities. Some students may pay to attend special cram or preparatory schools.'

The use of multiple choice question is attributed to the difficulty with which university students express themselves orally as well as in writing. The emphasis placed upon the feedback of information and the memorization of facts is attributed to the pressure and nervour tension that the examination itself causes in the student. In the particular case of introductory biology courses, these facts exercised an influence in terms of the background of students entering the course. The possible use of the renovated projects applied to secondary teaching is determined by the character of examinations. In some cases the examinations had to be changed to meet the objectives based upon these projects. (See the chapter 'Trends in techniques and criteria used in assessing student achievement').

If one considers that 15 years have already passed since the introduction of the Biological Science Curriculum Study and nearly as many since the Nuffield Project began, it is evidently necessary for a careful and detailed study be made of the effects of such programmes on students and their importance as elements modifying university courses. Such a study could be very helpful and perhaps serve as a guideline for those currently involved in formulating new curricula.

In those educational systems where several science courses such as physics, chemistry and biology are taken simultaneously during the high-school years, the effects of transference of attitudes and behaviour from one course to another would make it possible to clarify more specifically the long-range effects on the university student body of such projects as the Biological Science Curriculum Study, Nuffield, Chem Study, CBA, PSSC, etc. Curriculum changes even in the transition from one level of education to another, are sequential and should relate anterior and subsequent parts. Many youths who were involved in teaching projects in biology during their high-school years (projects such as the BSCS and Nuffield) are now undergraduate or even post-graduate students. This permits verification of the long-range effects of such projects by the students themselves when they enter an environment where there are few opportunities for self-expression, due to crowded classes, and where information itself is highly prized.

The influence of the BSCS has been analysed in several studies. Mayer, Allamong, Carter and Nakostem in a special issue of the BSCS Newsletter (BSCS, 1971) reported the influence of the different versions of the BSCS in the performance of biology freshmen and in the organisation of introductory biology courses. A study by Bennet (1975) of 857 students enrolled in the introductory biology course at Iowa State University showed that 95.92 per cent of the sample had taken biology courses at the secondary level and that 37.59 per cent had been subjected to at least one of the BSCS versions. Comparing the final grades of these students (the average of two tests and one final examination) Bennet found that those students who had not used BSCS textbooks obtained better grades. This finding can serve as the focal point for the formulating of a series of hypotheses and problems. How are the introductory courses organized? What kind of methodology is employed and what does the content encompass in these courses? Could there be any discrepancies between the educational objectives of university courses and the BSCS? Are the examinations valid measurements of these students' performance? How deep is the gap between secondary and university education?

A number of relevant questions will arise that will help researchers in their attempts to make the current curriculum preparation process more efficient for all concerned.

UNIVERSITY TEACHERS

There is no doubt that the most important element in teaching renovation and transformation, regardless of the level considered, is that of the teacher/professor. At the university level the problem has particular facets. When one compares the pedagogical training of university teachers with that of elementary and secondary teachers, the former are in a disadvantageous position due to the fact that they have generally received no formal training. The vast majority of introductory courses are conducted by beginners – instructors or assistant professors – who generally have to divide their time between lecturing at the undergraduate level and working for their Master's or Ph.D. degree. Besides their limited experience in teaching, they also show little interest in problems of a didactic nature since their main aspiration lies in the area of research. As their academic career is centred around the preparation and publication of research papers, teaching is considered to be unavoidable burden.

Although there is an urgent need for programmes that train teachers how to teach in order to improve higher education, they are very seldom offered. As faculty members insist on their independence and the right to carry out their work in isolation, they seldom go to the trouble of worrying themselves about teaching problems. These are always subordinated to the higher aims and goals to which professors dedicate themselves – research.

As a general rule, university teachers are trained, or train themselves, by the trial-and-error method. When they are initiating their careers, their classes are based upon those they attended when they were students, and from then on they begin to develop their own personal styles. This is done at the cost of many students and during many years during which students must support the errors of the professor until he begins to hit the right note, if this in fact happens.

Attempts to improve the situation described above vary from formal training sessions, usually conducted by the more experienced faculty members, which normally are no more than disguised administrative meetings, to real training courses. A recent study that analysed the training of instructors and assistant professors, carried out by Stockdale and Wochok (1974), verified that in the 50 colleges studied 80 per cent offered training courses consisting of one initial meeting followed by weekly gatherings that, in the main, dealt with administrative procedures and problems. The colleges that offer training programmes tend to organize them on four basic lines: the first concentrates on the discussion and presentation of teaching proceedings and methods that tend to increase student performance, the second deals with class or course planning, the third tries to help the instructor formulate and analyse examinations and other means of student appraisal, and the fourth emphasizes the philosophy, history and aims of higher education. Other programmes, although less frequently employed, include those dealing with the improvement of course content and those concerned with educational psychology. Although Stockdale and Wochok's study was not restricted to biology teachers, the results give an idea of what is in that field happening.

There are some important points that should be considered by institutions willing to improve the situation as regards the use of specially trained staff to teach the biology introductory courses. As at the secondary level, status and promotions should be based upon teaching activities. In this regard, Rowe (1975) writes: 'It could be argued that in many cases the programmes and materials developed and the biologist who finds a more efficient and effective way to teach glycolysis or the Krebs cycle have had as important a contribution as their colleagues who are engaged in other types of research'.

The establishment of interdepartmental commissions which serve as a type of consultant service in educational matters seems to offer good prospects for improving teaching at the university level. A service of this kind has already been instituted in Brazil by the federal medical colleges. A central co-ordinating body exchanges materials and experimental results, promotes periodical meetings and administers courses. The service has at its disposal a bank of examination questions and answers, and a list elaboration of behavioural objectives for basic courses. It is re-

sponsible for up-dating courses for professors, organizing special programmes for weak students, and preparing tests.

Two inter-college projects can serve as examples of co-operative efforts by several institutions to produce teaching materials for biology introductory courses. One is a joint effort on the past of biology departments in five British universities (Bath, Birmingham, Glasgow, London and Sussex) to develop a biology curriculum project. The aims of the project are to produce new teaching materials in biology, and illustrate how learning methods could be improved by the use of educational technology (Dowdeswell, 1974). The Co-operative Curriculum Improvement Programme Biology (BIOCO–TIE) is the result of work by thirteen junior colleges campuses in the United States to prepare materials and disseminate scientific and technical information for use in introductory biology courses. (BIOCO–TIE, 1974). The University of Texas, in an attempt to improve its teaching situation, organized the Centre for Teaching Effectiveness with the following functions: to organise courses for faculty members, especially for instructors and assistant professors; to provide consultation services in course design; to organize seminars to help improve teaching abilities; and to survey campus facilities and suggest better and more efficient ways of using these resources.

In some cases, science professors are reluctant to establish this type of exchange programme. Science teaching centres, when they exist, could serve as a bridge and a meeting point between the various scientific institutions and those who are interested in teaching and educational problems. The commonest form of collaboration is joint research. Howe (1966) noted that 21 of 33 centres studied were carrying out such interdepartmental research programmes. Catheral (1971), referring to science education at the Science Education Centre of the University of Sussex, wrote that: 'Through Science Education Centres the researcher's isolation is removed and ideas are communicated, likewise through the Institute of Biology communication between Centres can be established and ideas spread'. The materials produced in these teacher training centres – films, tapes, books, auto-evaluation material, and model programmes for course training – could possibly be considered as part of a programme of biology teaching improvement. A greater interest in teaching and educational problems could be aroused if some kind of linkage existed between the science departments and the science teaching centres.

METHODS

In general, biology introductory courses are organized to furnish information and the methodology of the professors reflects this tendency (CUEBS, publication 31, 1972). The most common processes for the transmission of information are lectures and laboratory exercises that confirm information previously received.

Lectures serve to provide students with a global view of certain course contents, help them to understand data and to solve problems, present various opinions and points, of view, and give information in an organized and interesting manner. Despite their obvious advantages, lectures also possess many disadvantages and impede or make student participation more difficult. What should be an intellectual exchange is reduced to a monologue that is anything but stimulating.

Small group discussions are currently popular in biology. This type of participation has the advantage of permitting students to express themselves openly and allows for direct question and discussion sessions with professors as well as with fellow classmates. What usually happens in practice, however, is that, due to the lack of preparation for group work, these so-called discussion classes are transformed either into lectures delivered to small groups or into unorganized talks without structure and without any definite direction. Such classes defeat their own purpose and end up exactly where they started (Parker, 1974).

Group work requires careful preparation and advance distribution of reading material

and guides to be followed during the discussion period. This is essential at least during the primary states so that a certain procedural order can be established. An interesting and practical suggestion given by Young (1974) is that each member of the group 'pays his ticket', that is, each furnishes his own written response to a question proposed during the class preceding the discussion.

The use of video tapes and films can be very useful aids in analysing and criticizing the classes. In poor countries where these means do not exist or are difficult to acquire, personal observations made by groups of professors of the same department or teaching unit could serve the same role and result in greater efficiency.

With the growing concern for social problems and the attempt to give relevance to biology courses, a new way of working with students has become popular - simulation and games. Probably because of the increased interest in community problems, this process, so widely used in the social sciences, has become incorporated into the natural science courses. Participants in science course simulations assume and defend the roles of different elements in society or of members of the community and interact so as to consider varying points of view and interest. The students acquire an understanding of the complexity of certain problems and the difficulties that arise when trying to reach acceptable solutions. When they have finally reached an agreement, the group members can verify the effect of their decisions by the reactions of their classmates (Crawford and Purcell, 1974).

In introductory biology courses, simulations are particularly useful in making students aware of the scientist's responsibility to society and the citizen's responsibility to science. Topics such as the construction of industrial plant, the destruction of forests, and the use of insecticides and pesticides are well suited to discussion of biological problems and are of social, economic and political interest. Students, who react enthusiastically to this type of activity, not only deal with problems related to their own field of study but also learn to work in groups, to respect confronting opinions, and to negociate and compromise in order to reach acceptable decisions.

If introductory biology courses, besides furnishing information about the basic biology concepts, are to give students a view of biology as a science and allow them to experience the scientific process, then laboratory or practical exercises are essential. A good balance between theory and practical including field work from the very beginning is essential.

Among the various objectives of laboratory work - to illustrate concepts and present facts, to teach techniques and methods, and to offer participation in scientific work - the most important is that the student encounters the unexpected in his results and tries to explain it. The laboratory is the only place where this process can occur. While many other aspects of the scientific process can be presented by varying methods and techniques, this objective is the exclusive property of experimental work. (see also the chapter on 'The impact of new instructional equipment and educational technology in the process of teaching biology'). At the Scottsdale Community College in the United States (Gray and Olson, 1975), the laboratory is open and the student can use it at his own convenience. Each experiment is divided into parts and students need not finish the whole project in one period. Instructions about use are given by film loops. Attendance is controlled by cards carried by the students; these cards are placed in a card holder which has a number of slots equal to the number of laboratory stations. When the slots are full, students know that there are no places left.

The development of a national technology to produce educational materials is a pressing and urgent need in developing countries wishing to provide good science teaching. Equipment production, the installation of a local industry to furnish educational materials based upon curricula designed to serve the interests and objectives of each country, and the production of class aids - texts, equipment, audio-visual aids, etc. - are essential.

An interesting experiment in this regard was conducted in Brazil. A series of fifty kits was produced for carrying out experiments in physics, chemistry, biology and geology. Each kit included sufficient equipment to conduct a series of experiments together with instructions and the

biography of a scientist celebrated in connexion with experiments to be conducted. This permitted a discussion of the implications and effects of scientific discoveries in a given historical context.

So as to make then readily accessible to the general public, the kits, were sold at local news stands. New series were offered every two weeks. One of the unexpected results of this project was the adoption of the kits in large numbers by secondary schools and even by colleges and universities where they were used in introductory science courses. Although the equipment was unsophisticated and the experiments were prepared for the secondary-level student, university teachers also employed them as they were the only available resources to which they could turn. By using the material provided in the kits, they were able to realize more sophisticated experiments which their courses demanted.

The papers published in the *Proceedings of the Third Asian Regional Conference on School Biology* are excellent examples of how local organisms can be utilized. Investigations with silkworms, hibiscus, rice and other grasses peculiar to the region (AABE, 1970) will allow the development of courses adapted to the area where they are given.

While there are many excellent laboratory manuals for high school courses, such material is very scarce at the university level. The preparation of laboratory manuals and teacher guides containing exercises and suggestions that present relevant problems and help develop good investigative habits instead of merely containing instructions that are mechanically repeated is another task essential to university teaching improvement.

Field trips are characteristic activity of introductory biology courses even though the problems they present to those in charge of planning are serious and take on different aspects according to the region where they are to be conducted. A teacher's guide dealing with the problems involved in field trip planning and the practical difficulties encountered, and furnishing suggestings for projects to be used in introductory biology courses would be very helpful, especially at this time when there is so much concern ecological problems and the conservation of natural resources.

TRENDS IN THE ORGANIZATION OF INDIVIDUALIZED INTRODUCTORY BIOLOGY COURSES

Individual student differences have been held to be the principal cause of one of the most popular trends in modern biology teaching - individualized instruction. The search for teaching strategies that take into account individual differences in personality, interests and previous preparation so that students can work at their own pace during their courses is a constant in today's discussions about biology course planning. The large number of enrolments, and the need to innovate in methodology and instructional materials have also played a role in the dissemination of this idea.

The pioneer work done by Postlethwait (CUEBS, 1971) at Purdue University gave the first major impulse towards the use of the so-called 'audio-tutorial approach' and the whole movement for individualized instruction. Kormondy (1971), at that time director of CUEBS, made it quite clear in the preface to his article *Modules - The use of modules in college biology teaching,* that much is hoped from this type of instruction as a remedy for teaching problems. 'I submit that the modules will perhaps become the major pedagogical tool in education - at all levels! But, a tool is a tool, a passive object which achieves its purpose only when used, the degree of achievement being dependent upon the degree of the user's skill. So it is with modules, as well as with textbooks, laboratory exercises, movies and all other accoutrements of academia'.

Modules, units of instruction or minicourses, are, in fact, instructional units with specific objectives, clear instructions for student work, texts and self-evaluation instruments. The advantages more frequently listed in support of the use of modules are that: they take into consid-

eration individual student interests by allowing for independent study; they avoid needless content repetitions for students who have already studied a given subject, and allow for remedial work for those whose lacking educational background; they allow for greater course flexibility permitting any number of different module combinations; they facilitate material revision since they are divided into small independent parts; they are already prepared so that the professor is freed from planning and routine activities, allowing more time for study, a more personal contact with his students, and more time to prepare other modules for future use; they can be exchanged between institutions thus forming a large pool of material that can be used by many professors and schools; and they can replace lecture classes with significant benefits.

Certain problems, however, may arise from the use of modules as a form of class instruction. From the practical point of view, two types of difficulties have been pointed out. The first centres around the difficulties encountered in establishing and maintaining the spirit of self-discipline necessary for independent study among students, the second is related to material maintenance and control.

Even though modules were designed for individualized instruction, many authors feel that they can be adapted to group learning. While this solution may be satisfactory for some regions, it would be very difficult to apply in countries and regions where small colleges would be unable to organize such a complex mechanized control system.

The following chart summarizes some of the individualized courses for introductory biology.

Institution and name of project	Main aspects
University of Wyoming; Geisert (1974)	Instructional procedures - open laboratory, audio-tutorial, programmed learning, small group instruction, student-to-student instruction.
Iowa State University, PAS (Phase Achievement System); Dolphin (1973)	Audio-visual tutorial modules, visual and audio tapes, lectures, laboratory work.
Inter University Biology Teaching Project (IUBTP), University of Glasgow; Dowdeswell (1974)	Independent study, programmed instruction, audio-tutorial and tape slide.
Biological Science Curriculum Study - Minicourse development; BSCS (1973)	Material - study guide, slides, film strips, film loop, films, audio tape, laboratory equipment. Independent study, programmed instruction, laboratory investigations, field experiences and audio-tutorial.
AIBS - Project Biotech, American Institute of Biological Sciences; Ehrle (1971)	Materials to teach biologically related technical skills and and techniques; programmed units, slides, film strips.
Harvard School of Public Health "What people eat?"; Raw (1975)	Based on classroom experiments. Includes lectures, seminars and field projects.
General audio-tutorial independent study, University of Arizona; Gaddis (1972)	Independent study, programmed instructions, laboratory investigations, discussion sessions, field experiences and audio-tutorial.
Kansas State College, Individualizing instruction; Kurtz (1971)	Independent study, discussion groups, laboratory experiments.
Unit Bank Biology, IPN, West Germany; Schaefer (1972)	Lectures, seminars, discussions, laboratory demonstrations. Relates biological concepts to cybernetic concepts.
Video-tutorial instruction, Rhode Island Junior College; Ganz (1974)	Lectures, laboratory sessions using video-cassettes in conjunction with student laboratory material.
Principles of Genetics, University of California at Davis; Fisher (1974)	Video-tape modules, textbook reading, problem assignments. Students meet with instructors for clarification lectures for 200 students weekly.

OBJECTIVES AND EVALUATION

It is currently recommended that behavioural objectives (instructional, educational, operational, etc.) be defined prior to examination preparation. Determining the minimum level of performance at the beginning of the course is a valuable way of verifying student progress during the course and also of preparing examinations. What usually happens is that course objectives are prepared during the planning phase and then forgotten. These objectives reveal themselves and students recognize them only during examination periods since professors usually test only what they consider to be important. (See also the chapter on 'Trends in techniques and criteria used in assessing student achievement').

The examinations used in university courses generally reflect the kind of course that is highly informative and compact and which is limited to the lower categories of the cognitive level. These courses seldom reach the higher level, of the various taxonomies of educational objectives. The very structure of the university is also an obstacle to the improvement of evaluation and planning techniques. Large student bodies, teachers' limited free time, the impossibility of a more personal contact between faculty members and students, and administrative demands, make the grading system a source of friction when it should be a source of information about student progress. Seminars for faculty members that deal with the problems of evaluation and prepare publications with suggestions and examples of evaluation instruments would help to minimize the problem.

MEANS

University textbooks are, more than at any other level of teaching, guides and determinants of the nature and characteristics of biology introductory courses. Textbooks have always served as indicators of course approaches. Some textbooks were of great influence in teaching and indicate when teaching under went a transformation. The transition from the morphological to the phylogenetic approach depended on the writing of a textbook that would transmit this view to a school-aged audience.

In developing countries, the influence of innovating research publications is delayed, especially because translations are necessary. Besides the need to understand foreign languages in order to keep one-self's up to date with publications, scholars in these countries have financial and communication problems in the acquisition of textbooks and other materials.

The publication of books divided into series with units that treat specific themes marked one stage and presented many advantages. They permitted greater course flexibility and the possibility of frequent material up-dating as well as a reduction in price. As the preparation of textbooks for universities does not adopt the procedure used for the development of high school curriculum projects - interdisciplinary groups dedicated to the preparation of reading material, laboratories, practical activities, films, etc. - the use of serial-type textbooks would permit student exposure to different ideas as presented by different authors.

The preparation of an anthology of possible alternatives for biology courses, including suggestions for experiments illustrating basic principles which could be adapted to different regions, was recommended as a possible way to develop an international programme. (see the chapter on 'Regional and instructional co-operation for the improvement of biology education').

CONCLUSION

Several points emerge from the study of trends in designing introductory university biology courses. Variations in the size and composition of the student population will create a need for

the production of more and different media. Progress in technology will produce films, slides and complete programmes that will differ from student to student according to their personalities and interests.

Introductory biology courses will reflect concern with the social implications of biology, as well as transmitting information about facts and processes is biological research.

Institutional changes and modifications of the higher-level education system will generate different solutions in terms of class organization, new courses and the integration of biology courses and community. A greater number and increased diversification of professional options will produce a need for different curricula in introductory courses.

Research will be needed to produce better courses, and improve the efficiency of education at the beginning of university education. Different universities and institutions will combine forces to produce courses and materials that can be used in different campuses and schools.

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The contribution of biology to public interest and public education

INTRODUCTION

At the outset it is important to acknowledge that the term 'public' is vague and ill-defined, and in the present context signifies those who are not trained biologists. Outside of our own specialities and interests, however, we all become laymen; the further one moves from the speciality of training the more general becomes one's knowledge, and the more one becomes a member of 'the public'. This fact is too often forgotten, and there is a tendency, on the basis of specialized knowledge and training, to assume a spurious authority and to make superficial generalizations about the work and attitudes of others.

EXTENT OF PUBLIC INTEREST

The term 'public', then, is extremely vague, referring to millions of people of all ages, at all stages of education and with a variety of aptitudes and interests. Some sectors of the public display substantial professional or amateur interest in science.

There is undoubtedly a great deal of overlapping membership between organizations concerned with natural history and the environment in all countries. The size of the group may be increased by considering other, less academic interests e.g. if it is assumed that people involved in athletics, gardening, angling, etc., have an active interest in, and concern for, some aspect of biological science. This kind of information may be obtained by a public opinion-poll method; in determining the extent of public interest, such a method may be valuable in some countries, but its reliability is often questioned. In some developing countries, 'market place' opinion might give a reliable indication of community feeling. Behavioural indicators (e.g. adoption of new agricultural techniques, extent of litter) need to be investigated as possible methods of obtaining information.

If society contains both a minority element that is informed and articulate and a less articulate majority, it may be that the latter can be more readily reached by way of specific social or recreational interests. If a 'peer-teacher' approach can be coupled to this then the

articulate opinion leaders can be used as a means of communicating with the majority. The method of coupling a particular socio-medical education programme to an existing community organization is outlined by Muslim (1975), in South-East Asia, while Lee Joo Hyun *et al* (1975) describe the role of local opinion leaders in Korea.

THE BENEFITS OF PUBLIC INTEREST

What is the benefit to society and to scientists of a balanced and well-founded interest in, and appreciation of, science (especially biological science) by the general public? The answer to this question may be sought in the context, firstly, of the science-and technology-oriented and resource-limited society in which the peoples of the developed countries live, and secondly, the importance of innovations in agriculture and family planning to the many peasant and farming communities of the world. As pointed out by Emmelin (1975) an understanding of the functioning of the environment is a requisite for coping with both technological development and underdevelopment.

For the purpose of this chapter, pure sciences, the applied sciences and the social sciences are not separated when considering benefits; in many respects, biology serves as a bridge between each of those facets and forms of science. A list of benefits might include the following:

- facilitates determination by policy-makers of expenditure priorities in a resource-limited society;
- promotes understanding between policy makers, planners and the public;
- improves understanding and co-operation in the fields of diagnostic, curative, preventative and social medicine;
- improves understanding and co-operation between the agriculture industry and the public;
- increases and promotes understanding of the values of environmental conservation and land management;
- enhances opportunities for leisure by adding understanding to aesthetic considerations of the environment and wildlife.

The benefits to society in general are clear and resolve themselves into 'a better informed electorate'. The value to the individual in society is more difficult to define, but fundamentally consists of increasing understanding thereby diminishing uncertainty and anxiety, enhancing 'the quality of life', imparting a sense of participation, and encouraging personal decision making so that freedom of choice of action is extended. The value to the scientist is, in the last resort, that he can continue to expand and pursue his science with the understanding and support of the public.

EDUCATION

Public awareness and understanding are largely based on information and education. The use of posters can be a powerful and inexpensive means of conveying information, but informing is only one step in the process of education. It is important to view the formal components of science education (i.e. school, college and university), the non-formal (i.e. organized, but outside the formal system) and the informal (e.g. radio, newspapers etc.) from the standpoint of impact and influence on the public.

Formal education

As far as the biological field is concerned, even within one country the formal levels of public

education vary considerably. In part this variation is due to the mixed age structure of the population; age-group knowledge will reflect the content and emphasis of courses given in the corresponding school years. It will also depend on the different stages reached in the education spectrum by different members of the public.

In designing appropriate curricula for these various levels, account is taken of the stage of development reached by the individual or the age group and the educational objectives to be achieved. In reviewing a wide range of curricula it is possible to derive a list of objectives which are either explicitly common to most, thus:

- fostering and sustaining interest in the learning process and the need to understand the causes of events;
- training in the skills and attitudes of the scientific method;
- imparting factual knowledge;
- imparting motor skills;
- stimulating pupils to maintain a science component in higher education;
- stimulating the application of the principles and skills of science to relevant areas outside science;
- promoting an understanding of science in the cultural life of the individual and society, and thereby promoting the breakdown of the so-called two cultures (arts-based and science-based);
- training for specific careers in biology.

Clearly not all of these aims and objectives are relevant at every level of education (See Chapter 1). From the point of view of public education, the main concern is perhaps course content *up to the first school leaving point* since for the majority of the population that will conclude their formal education in biology (and probably science). To a lesser degree in terms of proportion of the population involved, but probably to a critical degree in terms of positions held in society, consideration should also be given to those in the tertiary education sectors whose aims, interests and careers lie outside biology but who may study the subject at a subsidiary or minor level (the often despised 'service-course' to non-biology students). Taking these two levels as examples and looking at them purely from the public education viewpoint, it is useful to consider what curriculum-planners might include at such levels bearing in mind the six values listed earlier and the need to establish a foundation for the informal component of education discussed below.

Table 1 presents some ideas as a basis for discussion. It is not put forward as a model curriculum but merely as an indication of possible subject areas which can be related to major social issues. It is important in using such material not to set unrealistic goals of attainment. It is clear that a high degree of selectivity must be applied, and there is much scope for differences of opinion and emphasis.

Non-formal and informal education

In spite of great efforts in the developing countries, up to 50 per cent of the children and adults in some countries will not achieve minimal levels of formal education either through lack of opportunity, non-participation in the systems provided or 'dropping out'. A less extensive but similar limitation of the formal system is also clear in many of the developed countries of the West. Indeed it seems likely that in most countries the influence and impact of biology will be produced through the non-formal and informal levels rather than through the formal levels. The similarities between 'developed' and 'developing' countries in this respect are striking.

Non-formal and informal components of education will be effective forces, firstly in parallel with the formal component and, later, in succession to it. To a large extent the interaction of individuals with the components will produce a great variety of responses but this is also true

at the formal levels of education and need not prevent at least a superficial examination of the vehicles of these components of education and some of their likely consequences.

Listed below are some of the ways in which non-formal and informal education are propagated: broadcasting (sound-radio and television); books; public meetings and lectures; newspaper and general magazine articles and advertisements; specialist magazines; films; zoological gardens; botanical gardens; museums; nature trails and forest parks; tourist interpretation centres.

Table 1 Biology Curricula

A. Minimum curriculum for the first school-leaving point.

Topic	Percentage of time
Origins of the planet and its life. The variety of life, its nature, extent and evolution Basic animal and plant morphology. The evolution of primates, especially man. Time-scales.	20
Human structure and function. Reproduction, development, growth and senescence. The laws of behaviour.	20
Human types, variety in the human animal. Genetics and human genetics. Nature, nurture and their interactions.	10
The ecosystem concept; the evolution of ecosystems. The scavenger/hunter, agricultural and industrial evolution of man. Ecosystem management in the twentieth century. The space-ship Earth.	25
Population biology, population growth. Social medicine, its growth and implications.	10
Contemporary biology, present and forseeable problems in agriculture, fisheries and medicine. The work of the scientist (using specific examples). Pure, applied and social sciences. Continuing education in science.	15

B. Minor course (one semester) at university/college standard. No prior knowledge other than that in section A.

Topic	Percentage of time
The human species and culture, its evolution and diversity. Mendelism and man, racial and sex differences.	20
Human reproduction, growth and development - factors controlling and limiting properties of populations. Health and disease, biology of major diseases and abnormalities (physical and mental), preventive and curative medicine. Food and nutrition, parasites. Human behaviour and mental health.	30
Earth history; biogeochemical cycles, global energy sources. World ecosystems - their relationships to man. Resource biology - agriculture, fisheries, forestry. Cropping and optimization. Pests and diseases.	25
National and international organizations and programmes (e.g. Unesco; FAO, WHO, ICES, ICNAF, etc.). The work of intranational organizations, e.g. research councils, nature conservation councils (use specific examples).	10
The funding of science; the costs and benefits of scientific research, the time-scales involved (use specific examples).	15

It is difficult to place these in any order of importance but some are so obviously influential and far-reaching as to require special attention. Many of them require a literate and relatively affluent society in which to be effective.

Broadcasting, whether radio or television, must rate as one of the most potent sources of informal education. The great advantages are that there is no reliance on the literacy of the audience, while radio at least is relatively cheap and most individuals have access to it even if receiver sets must be shared. In more affluent societies, television is undoubtedly the major potential influence, with colour an especially valuable reinforcement. Sweeney (1971) was led to the conclusion that for communicating family planning advice the combination of picture

and sound has the greatest impact. Assessing the impact of broadcasts is now a well-established and routine part of the general audience research activity of broadcasting authorities. There is no doubt that biological programmes are very popular, especially those with a wildlife theme and those based on aspects of human physiology and behaviour.

A number of British Broadcasting Corporation television audience research publications provide useful examples for discussion. Studies are made by means of questionnaires and interviews, care being taken to ensure a valid sample in so far as sex, age, socio-economic group, professional interest-group, etc., are concerned. Reaction-indices are obtained for entire programmes, parts of programmes and subjects of programmes; viewers' attitudes and knowledge before and after viewing are also measured. One such study relates to the programmes *Matters of Medicine* broadcast in 1960. These dealt with the subjects of immunization and coronary thrombosis, and were watched by about 8 per cent of the population of the United Kingdom (3,750,000 persons). The reaction of the lay audience can best be indicated by the following quotations from the report.

> '*Immunization.* The audiences thought the programme had had a high propaganda value. Several viewers suggested that immunization should be compulsory. There appeared to be genuine satisfaction with all the medical speakers.
>
> '*Coronary thrombosis.* They commented that the programme contained much helpful information and that it was easily understood and fairly reassuring. A small minority critized the depressing and disquieting nature of the programme.
>
> '*Disabling diseases.* Most viewers thought the subject had been discussed in a balanced, sensible fashion, and never frighteningly, a minority contended that the material was unsuitable and unnecessary for general viewing and that it might encourage hypochondria. A few considered the proceedings profoundly depressing - containing little comfort for the afflicted.
>
> '*Living longer.* Most viewers emphasized the interesting nature of this programme. A small number wrote that it was "very boring".'

The reactions of the medical practitioners in the survey sample were broadly in agreement with those of the lay audience. A few additional points are made in the following quotations;

> '*Doctor's views on the use of TV for medical subjects.* 83 per cent were in favour of showing such programmes and the rest against. The minority felt that the dangers outweighed the possible advantages. Education should take priority over entertainment value, great care should be taken to avoid creating fear or anxiety. Such programmes should be put on with caution and responsibility in full consultation with the medical profession'.

The *summary of findings* in the report was as follows: 'The effect of the programme appears to have been to increase considerably the number of people who said they 'worried' about coronary thrombosis (from 18 per cent to 28 per cent) but not to have increased the proportion who were *very* worried about it. On the whole the programme also tended to increase the number of people who were concerned about growing older, the welfare of older relatives, overwork, illness and physical disability, particularly the number who worried about illness and the welfare of older relatives, but again not to increase the proportion who were very worried. The evidence is that the programme considerably increased viewers' knowledge of coronary thrombosis though much ignorance remained. The programme did not greatly affect viewers' attitudes towards general practitioners and towards the progress of medical science. There was some evidence of rather greater confidence in general practitioners and of more awareness of the progress medical science has yet to make. The programme does not appear to have made much difference to the incidence of anxiety of hypochondria'.

Another human biology programme (broadcast by the BBC. in their *Horizon* series in July 1972) was potentially more 'delicate'. This was entitled *Sex can be a problem* and dealt with such sexual difficulties as frigidity and impotence. A case-history approach was used. The audience

amounted to 4.8 per cent of the population (2,400,000 people). The 'middle-class' was heavily represented in the audience (perhaps 50 per cent of all viewers, although this class amounts only 33 per cent of the total population). The audience was predominantly middle-aged (60 per cent in the 30-49 age group, very few under 15 years of age and only 20 per cent over 50). The following quotations from the report once more throw light on the contribution of such programmes to public education.

> '*The Programme.* Research into the effects of mass communication strongly suggests that programmes dealing with entrenched attitudes and taboo subjects - as this one did - can rarely be expected to produce massive attitude changes - whilst even the conveying of information can be effectively blocked by scepticism on the part of the viewer.
>
> '*Extracts from summary.* The programme was widely regarded as informative, clear, in good taste and not embarrassing. Far from persuading viewers that sexual problems should be regarded as matters for treatment by the medical profession - the programme appears to have done the reverse. In view of the emphasis placed on the inadequate training of doctors in these matters such a result is, perhaps, not surprising. Despite increased unwillingness to consult a doctor, considerably more viewers than non-viewers were 'completely confident' that sexual inadequacy was curable. The contrast between the enthusiastic reception given to the programme by both viewers and non-viewers and its meagre effects on attitudes and knowledge is not unique'.

Turning to wildlife programmes, the following quotations from two reports illustrate the uses and limitations of the media in relation to matters of conservation.

> '*Wildlife safari to Ethiopia.* However frequently or infrequently they watched wildlife programmes, viewers were overwhelmingly in favour of protecting and conserving wildlife, 84 per cent strongly agreeing that "it's very important that rare animals and birds should be protected from harm". Nevertheless most of them (63 per cent) also support the proviso that "human beings always come first".
>
> 'The audiences were between 6 and 7 million, (i.e. 12-14 per cent of the population aged 5 years or over) and all programmes had high reaction indices ranging from 76 to 80. 'The effects' study, although based on the responses of small numbers of viewers and non-viewers, showed that watching *Wildlife safari to Ethiopia* did significantly increase viewers' knowledge of the country. However, the increase was not very great, viewers' marks increasing from an average of 12 out of 30 to 17 out of 30. Effects of the series on viewers' knowledge of, and attitudes towards, wildlife generally were even smaller'.

An analysis (Rowson-Jones and Salkeld 1972) of the influence of the mass media (especially radio) in sub-Sahara Africa with regard to family planning information presents other aspects of the uses and limitations of this form of education. The following data, taken from tables in that review, show that there is very significant coverage by radio in Africa:

Unesco targets for minimum media coverage/1000 people	Actual coverage in Africa in 1970/1000 people
100 copies of a daily newspaper	10.4 copies
20 cinema seats	18.0 seats
50 radio sets	55.7 radio sets
20 television sets	1.8 television sets

Not only is the coverage good, but a great deal of information is available on the characteristics and reactions of the audiences. Two surveys may be considered particularly valuable. The first concerned radio and T.V. audiences in Kenya. It showed that those who owned and listened to radio sets tended to be men rather than women, aged between 20 and 40, better educated than average and living in towns. The second survey (in Nigeria) gave information on the credibility of

the media in the following form:

Media	Very reliable	Quite reliable	Not reliable
Television	71.7%	21.7%	4.7%
Radio	69.2	18.5	6.2
Magazines	66.2	24.3	8.1
Newspapers	59.6	24.4	16.2
Posters, etc.	60.0	10.0	30.0
Cinema	36.4	21.2	39.4

Clearly, in communicating information on which a family planning programme is to be based, such details as those above must be taken into account. A set of sample scripts are included in an article by Riitho (quoted in Townson-Jones and Salkeld, 1972). The scripts are often short, designed for programme or advertising spots lasting for 10 seconds to 10 minutes. Some examples are given below:

BOTSWANA

Audience:	Mothers of young children
Time:	30 seconds
Man:	Mother! Tell me why your baby looks so healthy. What are you feeding him with?
Woman:	Nutritious food, good care.
Man:	How do you manage to give so much care to one child?
Woman:	We have been to the family planning clinic. They help you have babies just when you want them. Why don't you take your wife there?
Man:	We will go tomorrow. Thank you.

MAURITIUS

Audience:	Parents (Hindi speaking)
Time:	10 seconds
Announcer:	Baas do ya teen bache (Two or three children are enough). Kam baache ho to ounka bojh ootha Sakte ho (If less children, you can support them). Acha Khila Sakte ho ounhe acha para Sakte ho (You can feed and clothe them properly). Jeisi bhi Chaho ounki takdeer bana Sakte ho (Do as you like, their future will be bright).

NIGERIA

Audience:	Low income families
Time:	30 seconds
First woman:	Good news! Good news! Good news!
Second woman:	What's all this news of yours about?
First woman:	It's all about family planning.
Second woman:	What is family planning?
First woman:	Family planning helps you to have your baby when you want. It will help give your husband time to save money and perhaps improve your children's education.
Second woman:	Where can I find out more about family planning?
First woman:	There are clinics all over the country, in Government and missionary hospitals. Family planning has helped me bring up healthy and strong children.

Turning to the printed word and the role of books, magazines, etc., iliteracy may represent a barrier, but there is the advantage of permanency; the material can be read, re-read and passed on. Biological titles and subjects are popular, regularly appearing on the best-seller lists in most countries. Once more, wildlife stories are especially popular. There are few publications which appeal to specialist and non-specialist readers alike but there are nonetheless some, for example *The New Naturalist* series published in the United Kingdom by Collins.

Popular medical books (e.g. those of Dr. Spock) are also generally regarded as having great influence, but again there appears to be no quantitative information available.

Information on the impact of most other forms of informal education is at least as difficult to obtain and we are reduced to conjecture and speculation. The BBC data clearly indicate that although the education process probably cannot start without first capturing attention and interest, yet interest is only one step in the process and does not guarantee retention of information or change of attitudes. Perhaps no better example of this exists than the government-backed educational exercise in the United States and elsewhere to reduce cigarette smoking. It is not practicable to consider in detail all varieties of informal education, but even a superficial investigation of each leads to the conclusion that in an advanced economy such as that of the United Kingdom there is no lack of information available. The problems arise in matching this to the opportunities and willingness of the public to receive and assimilate it. The effects of even the most carefully planned programmes appear to be short-lived and more attention will need to be paid in the future to the problems of public receptivity, retention and application.

Science and society

Science does not present a uniform face to the public; applied science is easily comprehended but often distrusted and thought to contribute to environmental pollution. 'Pure' science is much less well understood, and at times (e.g. in relation to experiments on living animals) collects its share of odium. Research workers have in the past been slow to accept that they have a duty to inform the public and that they need to learn the necessary techniques. For conveying such information. The inevitable confusion in the minds of the public impairs progress toward an understanding of many major social issues. To prepare a comprehensive list relevant to all societies is difficult, but some of the major issues common to many countries are as follows:

1. Aspects of social and preventive medicine (e.g. uses of alcohol, tobacco, other drugs); 2. age, infirmity and handicap problems; 3. advanced and novel surgical techniques; 4. sexual problems; 5. eugenics; 6. population regulation; 7. racial understanding; 8. the role of women and children; 9. land-use; 10. food supply; 11. factory farming and intensive agriculture; 12. pollution; 13. Educational opportunities; 14. advertising and the manipulation of public attitudes and opinions; 15. housing plans; 16. the use of leisure.

On a world-wide scale, the contributions of biology to public education are primarily limited in two ways.

1. In countries where literacy levels are high, availability and accessibility of information are rarely limiting factors, whereas receptivity, retention and application may be. Only a section of the population seems to be receptive (with a large bias in favour of the middle-classes) while retention levels may be low and public attitudes resistant to change.
2. In countries where literacy levels are low, the accessibility of information is superimposed on problems arising from the unavailability of information.

In both cases, the result is a severe limitation on the understanding of science and scientists by the public. To this extent the effectiveness of science policy is bound to be restricted, and in some fields (e.g. the uses of energy, the management of the environment, aspects of personal and public health) such limitations may have considerable and costly consequences.

In circumstances where the levels of formal education in biology are insufficient to permit the public to fully understand the principles and practices of science, effective non-formal and informal methods of education become of increasing importance. At present the effectiveness of such methods is uncertain. Sardman (1974) and Linke (quoted by Emmelin, 1975) both conclude that the effectiveness of the media in educational terms is very limited, due among other things to superficiality of approach, the emotional nature of the message and, in some cases, associations with advertising of products which are regarded as being in some ways anti-social.

It would also seem that the 'passive' approach, linked in Western countries to a strong entertainment element, is not enough to ensure retention and application of information. Other, more active approaches with increased public participation may need to be devised. Such public participation could take various forms. One might be the involvement of groups of people in project work on a community basis, with the projects selected to match a particular need or interest (e.g. a conservation project, a 'protein-production' project, a family planning project). Another approach might be to follow-up broadcast programmes with locally organized lectures, excursions and further reading. In pursuing a policy of participation, formidable problems of public acceptance need to be overcome. There is a need for the establishment of a profession of 'community teacher" (analagous in many aspects with that of health visitor) responsible for public education after the statutary school-leaving age. Members of this profession would co-operate with, for example, science journalists. Their basic education and skills would be similar to those of teachers within the formal system, but they would require particular trainings in mass communication techniques. National and regional 'resource-banks' and an appropriate administrative network would be needed.

To some extent the Open University in the United Kingdom, the Radiophonic schools in Latin America and the University without walls in the United States forshadow such a development. The proposal is a long-term one, will require considerable manpower and it will not be inexpensive to implement. But there seems to be no escaping the conclusion that personal attention and involvement is probably the most effective long-term method of furthering public education. Once more, family planning organizations have given a lead, and the concept of trained field workers forms the basis of most of their community education programmes; inadequate training of field workers is inevitably counter-productive (see, for example, Cernada, 1970). Most important of all, if the aims and content of the education conflict with the social or economic situation of the people, the programme will appear utterly unreal and irrelevant.

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Regional and international co-operation for the improvement of biology education

Working in biological education these days one soon realizes that the rapid advancement in the teaching of biology in all parts of the world owes much to a great deal of co-operation. Co-operation is not only between students and their teachers, but among educators, scientists, administrators, curriculum writers, equipment suppliers, course evaluators, school plant planners, governmental officials, science supervisors, and many, many others. Overlying all these interactions are highly important activities that cross over political, social, cultural, economic, religious, and physical barriers and lead to a highly beneficial sharing of knowledge through regional and international co-operation. The bodies concerned range from such well known organizations as Unesco to those that impinge on only a few school districts. All of them, however, have the same general goal - the improvement of biology teaching wherever it exists.

The purpose of this chapter is to survey and review the developments and trends that seem to be emerging in the arena of biological education by summarizing a few specific examples of the myriad activities going on throughout the world. These indicate the needs that groups are attempting to meet and suggest recommendations for future direction. In these days of educational concern, literally hundreds of examples can be cited of on-going co-operative activities that affect biology teaching. Many such programmes may have been inadvertently left out, but this section does identify some particular by active groups including those mentioned at the 1975 IUBS/Unesco International Congress in Uppsala, Sweden.

TYPES OF CO-OPERATING GROUPS AND ACTIVITIES

Unesco as a co-operative institution

Among the organizations designed to encourage co-operation on an international scale is Unesco. While its headquarters is in Paris, it operates regionally so as to enable developing countries to help themselves by co-operating with other countries who have already found solutions to similar problems.

Unesco has used the co-operation of interested individuals to improve biology teaching. It may be useful to cite the types of activities most commonly undertaken. These include: the preparation of the classic co-operatively-produced *Unesco source book for science teaching* and its 1973 revision entitled the *New Unesco source book for science teaching;* the Unesco *Trends in Biology teaching* volumes; the Unesco Pilot project for the improvement of teaching in Africa local, regional and international workshops, training sessions and centres, writing conferences, and seminars; leader exchange; translation of publications; use of highly trained field experts; and special publications too numerous to detail. Inter-and intra-country scholarships are also sponsored.

ICASE, a Unesco-related co-operative organization

Unesco has been active in stimulating the formation of national science teaching associations, including biology sections within such groups. It was also instrumental in bringing into being an international organization of these groups, the International Council of Associations for Science Education (ICASE). Its organizational meeting in 1973 was held at the University of Maryland following a conference on the training of teachers for integrated science teaching that attracted 235 persons from 63 countries. Immediate ICASE plans include: the writing of a *Unesco handbook for science teaching* to supplement the *New Unesco sourcebook;* an *International directory of science teaching associations;* a quarterly newsletter; regional conferences; a manual on laboratory safety; and a teacher exchange programme. The United Kingdom will host the second meeting of ICASE in December 1975 which will interact with a Unesco conference on the evaluation of integrated science teaching and the annual meeting of the British Association for Science Education.

Scientists groups

Scientists have always been interested in quality science teaching. They band together in national and international organizations to share their latest scientific discoveries but they also set up educational committees to explore educational innovation. The committee that organized and co-sponsored the 1975 international biology teaching conference in Sweden, the Education Commission of the International Union of Biological Sciences, has as a major goal the stimulation of high standards of biology teaching at all levels of academic instruction. In addition to arranging conferences such as the above, it has been a main contributor to the Unesco New trends in biology teaching volumes. The IUBS Commission has a newsletter which reaches biologists and biology teachers in all lands and has the potential for communicating to classrooms ideas which are well worth sharing and using.

The IUBS is a biological branch of the International Council of Scientific Unions (ICSU) which also has an educational commission of its own. The ICSU Commission on Teaching Science (CTS) stimulates all kinds of co-operative activities and was a co-sponsor of the ICASE

organizational meeting. It holds international conferences, supports relevant educational studies, convenes symposia and is now moving into environmental education activities that will have relevance to biology teachers in all regions.

In many parts of the world, groups of scientists affiliate to specific programmes. For example, groups in the Latin American countries including the following: in Peru - PRONAMEC and IPEB (National Programme for the Improvement of Science Education and Institute for the Promotion of Biology Education), Brazil - IBECC (Brazilian Institute for Education, Science and Culture), Argentina - INEC (National Institute for the Improvement of Science Teaching), Venezuela - IVIC (Venezuelan Institute for Science Research) and CENAMEC (National Centre for the improvement of Science Education), and in Central America - CEMEC (Study Group for the improvement of Science Teaching) which includes Honduras, Guatemala and surrounding countries.

Teachers groups

In addition to working with scientifically-oriented groups such as IUBS and ICSU, biologists are establishing links with the numerous science teaching associations, particularly at the national level. The ICASE Directory lists over 50 national groups and many more are now being formed. There is also a strong trend toward regional organizations of classroom teachers and scientists. The Asian Association for Biology Education (AABE) is an example, while areas of Africa and the Caribbean also have similar organizations. Through their meetings, they have brought about improved communications among individuals and produced some valuable publications. In addition to their monthly journals, many have quarterly or bi-annual newsletters to keep members well informed on new developments. In Africa, for example, the Ghana Association of Science Teachers received a major tribute on the occasion of its 20 years existence in November 1975 when representatives of science teaching groups from many nations were able to see their accomplishments.

While some associations are all-encompassing some are limited to biology, and some like the French Teachers Association in Biology and Geology (APBG) and the Finnish Association of the Teachers of Biology and Geography, cover two disciplines with their membership.

Science curriculum development projects

Since 1956 scientists, science teachers, science educators and science supervisors have been eager to work co-operatively so as to produce updated accurate courses of study. Biology has been especially favoured in this work. The 1975 *Ninth Report of the International Clearing house on Science and Mathematics Curricular Developments* indicates that of all the curriculum projects undertaken in these 20 years, some 170 projects have biology as a major part of their work. Although projects with considerable financial backing such as the United States Biological Science Curriculum Study (BSCS), the British Nuffield Biology Projects and the Australian Academy of Sciences 'Web of Life' project are well known, a large number of others have also done fine work.

These project activities not only cross over boundaries existing within nations, they have been very effective in bringing together people and ideas from all over the world. The adaptation and implementation work have provided an outstanding example of large-scale co-operation. Individual countries can achieve rapid progress in their own work by not having to 're-invent the wheel' each time they develop curricular materials. The range of activities is worldwide and impressive (see past and present *International Clearinghouse Reports*). Governmental and quasi-governmental groups.

The ministries of education of a number of countries are actively involved in helping to improve teaching situations by co-operative support, stimulating ideas and furnishing funds to bring about needed changes. There have already been some excellent endeavors in the African Asian countries and the Middle East is moving very rapidly towards expanded educational support.

The governments of countries such as the United Kingdom and the United States, either directly or through quasi-governmental agencies, have been involved in numerous overseas educational activities. The British Council, with funds from the Ministry of Overseas Development, has held educational seminars of one to four weeks duration on various aspects of primary and secondary education including teacher education; sent specialists and consultants on tours to deliver lectures or conduct workshops; furnished personnel and finances for local curriculum development as in Kenya and the Caribbean; provided a great deal of information through the tri-yearly *Science Education Newsletter* and numerous bibliographies on science and mathematics curricular developments; and awarded scholarships, technical assistance grants, fellowships and travel grants for study in science education, including biology teaching.

The United States, through its National Science Foundation (NSF), has intensively supported science curriculum development work since 1956. Its activities have included such internationally important projects as the Biological Sciences Curriculum Study (BSCS) whose writers and staff members have worked co-operatively with their overseas counterparts. Workshops for teachers and professors were *held* overseas in respect of a number of the new projects. The NSF has tried to furnish valuable science education information by establishing and supporting the International Clearinghouse on Science and Mathematics Curricular Developments (The InC). In addition to its bi-annual *Reports,* it maintains a comprehensive collection of curriculum project 'soft-ware' (printed material including texts, laboratory books, teacher guides, etc.) and model 'hardware' (Laboratory equipment and audio-visual materials) from all over the world for perusal at the University of Maryland's Science Teacher Centre. Plans are now being formulated for an international newsletter from the InC that will help keep information flowing on as a regular basis.

In South America and the Caribbean, major activities are under way in several countries, with the programmes of Argentina, Brazil, Colombia, Chile, and the West Indies among the most important. More will be said about Asia in reference to centres and regional programmes. Canada has undertaken a number of co-operative programmes, as have most of the Scandanavian countries. France's Institut national de la recherche et de la documentation pédagogiques (INRDP, National Institute for Educational Research and Documentation) has some similar projects underway, especially in connexion with several European countries, North African countries and others south of the Sahara (educational research and retraining of teachers).
Bilateral groups.

In addition to the government funded groups described above that have as their focus projects outside their home country, there are organizations that operate with other countries on a reciprocal basis. In some cases there are teacher-exchange programmes as well as student exchange programmes. Some personnel from one country may be trained in another so as to be able to act later as consultants to both countries. Bilateral groups have been particularly active in European countries. In addition to organizing personnel exchanges and training programmes, such groups have furnished substantial financial support to less developed countries.

One multi-country operation involving some 70 groups in various countries was sponsored by the United States Agency for International Development (USAID). This was a co-operative four-year study designed to bring about more teaching of science as investigation. It resulted in the publication of three volumes on *Improvising Science Teaching Equipment: Biology, Chemistry,* and *Physics* which are still available in English from the University of Maryland's Centre and will soon be available in Spanish.

A highly popular bilateral activity was that originally set up as the Fulbright Scholarship

and Exchange Programmes. Many countries in addition to the United States now have similar arrangements.

Foundations

Almost every country has had some privately funded foundation take a serious interest in science teaching improvement and use co-operative means to be effective. Classic cases include those of the Asian, Carnegie, Ford, Nuffield, Rockefeller, Swedish, Sony and Volkswagen Foundations which give massive support to education. Many others are less familiar but highly effective and have been successful with curriculum development, mass education, audio-visual assistance, reference services, consultant teams and training programmes with biology and agriculture frequently major foci.

Universities

Although universities and colleges primarily serve their own nationals, an increasing number are heavily involved in international activities on a co-operative basis. They furnish special curricula, aid in curriculum development work, exchange professors, share research laboratory staff, develop resource centres, serve as locations for meetings and, in general, encourage their faculty to aid education at all levels. The next section details one of their major contributions to science teaching; the ongoing operation of science teaching centres.

Science teaching centres

A major development of science education in which co-operation should be high are the science teaching centres established in various countries. Although their activities and specialities vary somewhat they have some characteristics in common. Most have direct ties with a university or college, are involved in the pre-service and/or in-service training of science teachers, maintain physical laboratories for practical or demonstration work, furnish consultant help to interested groups, are involved in some kind of curriculum development work, have audio-visual capabilities, study laboratory equipment and facilities of a commercial and/or of an improved nature, and have many on-going co-operative activities, the effectiveness of which remain to be evaluated and increased.

Some representative centres that exemplify this type of operation might include those in Brazil, India, Israel, Japan, Jordan, Lebanon, the Philippines, Singapore, Thailand, the United Kingdom and the United States. While most of these are associated with one particular country, other centres such as the SEAMEO-sponsored Regional Centre for Education and Mathematics (RECSAM) in Malaysia and the APEID Asian Centre for Educational Innovation for Development (ACEID) are more broadly oriented. They illustrate to an extreme degree co-operation with multi-national aspects. These and the numerous other science teaching centres around the world help to stimulate progress and implement some excellent biology teaching techniques.

Regional organizations

As the geographical area concerned expands, the need for closer co-operation and attention to other viewpoints may become even more important. The support of the RECSAM Centre by the South East Asia Ministers of Education Organization is a good example. They have identified a

number of crucial educational areas such as science and are proceeding to bring about change. Other examples of regional groups are the West African Association of Science Teachers (WAAST), the Asian Association for Biological Education (AABE), the European Community Biologists Association (ECBA) and the Science Teachers Association in South East Asia. Their activities are expanded versions of those of national science teaching associations.

In West Africa, four countries – Nigeria, Ghana, Sierra Leone and Gambia – are co-operatively involved through the West African Examination Council in teaching and assessing Advanced Level and Ordinary Level Biology. The schools in these countries follow one syllabus and are examined by one agency, the West African Examination Council. Another organization which is involved in science education in that part of the world is SEPA, Science Education Programmes in Africa. Curriculum work has been an important part of their activity.

A major influence in the Middle East Region is the Arab League Educational, Cultural and Social Organization (ALECSO). It has many facets to its work and might be considered a sort of regional Unesco. Part of its programme consists of establishing science teaching centres and developing science curriculum materials. An example of related co-operation in the Middle East may be seen in the fact that over 15000 teachers have been seconded from Egypt to other Arab countries. Saudi Arabia is making extensive use of such regional co-operation.

While most of the science teachers associations, have national meetings, several also hold regional sessions. The British Association for Science Education is active regionally as are two United States groups that assist teachers, the National Association of Biology Teachers (NABT) and the National Science Teachers Association (NSTA).

Latin America has a number of organizations that are supported nationally and which should be mentioned here since they also play important regional roles. In Peru, there is the National Programme for the Improvement of Science Education (PRONAMEC) and the Institute for the Promotion of Biology Education (IPEB). There is the Brazilian Institute for Education, Science and Culture (IBECC) with numerous projects including co-operation with six science teachers training centres located in São Paulo, Rio de Janeiro, Recife, Salvador, Belo Horizonte and Porto Alegre. Two important organizations in Venezuela are the Venezulean Institute for Science Research (IVIC) and the National Centre for the Improvement of Science Education (CENAMEC). A regionally active group in Central America is the Study Group for the Improvement of Science Teaching (CEMEC), while the Andes Bello Convention for the Andean group is active across the borders of Bolivia, Chile, Colombia, Ecuador, Peru and Venezula. On the continent as a whole, the many programmes of the Organization of American States (OAS) are well known.

International groups

An international group with broad general interests in education, including biology teaching, is the World Council of the Teaching Profession (WCOTP). The Commonwealth Associations of Science and Mathematics Educators (CASME) has a more specific direction but functions effectively with most, if not all, of the Commonwealth countries. Both use conferences and publications to bring about valuable interactions.

The International Association for the Evaluation of Educational Achievements is a good example of international co-operation as it involved world-wide testing programmes for science and mathematics students in numerous countries. Designed as a base-line research study it enabled the participating countries to see how the training of such students in their own country compared with that in other countries. Although certain aspects of the testing procedures may be questioned, the high quality of co-operative spirit should encourage similar programmes in the future.

A specialized organization of interest to biologists everywhere is the International Assoc-

iation of Zoo Educational Officers. This association is very new and was formed officially on Copenhagen in 1974. Meetings to discuss co-operation had previously been held in 1969 and 1971. The membership is growing and their next meeting will be in London in June 1976.

RECOMMENDATIONS FOR REGIONAL AND INTERNATIONAL CO-OPERATION IN THE IMPROVEMENT OF BIOLOGY EDUCATION

Dissemination networks

A network system should be established to:

- encourage the exchange of information, ideas and experiences (especially about new teaching methods, living things used in the classroom, new curricula relevant to the needs of society, evaluation, etc.) among individuals and institutions throughout the world who are involved in some aspect of biology education;
- enable these individuals or institutions to make contact with each other for the purpose of exchanging services (methods, materials, especially inexpensive ones, funds, etc.) which are needed by some and which can be provided by others;
- make the National Commissions of Unesco more aware of the role of Participation Grants, ensure and improve the dissemination of Unesco publications through the right channels, such as the science teaching centres and the national biology teachers' organizations and their journals.

Publications

1. Unesco should continue and expand the compilation of the annotated bibliography on all aspects of biology education; distribution of such information should be effected through the proposed network.
2. Unesco should support internationally the publication and dissemination of case studies and reports based on practical experience. Such publications should be distributed through the proposed network.
3. Projects should be assisted which seek to incorporate the findings of relevant biological and educational research into the school biology teaching system of each country.
4. Regional journals for the publication of biology investigations by school pupils and teachers should be established and supported.
5. In view of the great need for curricula and learning resources adapted to local and national needs, biology resource books or teachers' guides should be prepared at regional levels to emphasize innovative techniques, methodology of teaching and its use in relation to local needs, local resources and their use, and information on the design and production of inexpensive but effective audio-visual and science laboratory teaching equipment; such resource books would supplement the *New Unesco source-book for science teaching*, the *Unesco teacher's guide on the biology of human populations* and the upcoming *Unesco handbook for science teachers.*

Training

1. Teacher exchange programmes should be initiated and efforts be made to minimize any hardships involved.
2. Regional and/or national science teachers' centres could be established to aid science

teaching at all levels. Each centre would be in active contact with all others through the proposed network.

3. Suitable specialists should be identified and properly used for the improvement of biology teaching to provide international co-operation in curriculum development and evaluation.

National study groups and meetings

Unesco should continue to support the initiation of national and/or regional groups in biology education; such groups should mainly consist of teachers and others actively involved in education. The already existing national study groups should continue to receive active support and be strengthened, in order to develop various activities such as: curriculum development, teacher-oriented workshops and seminars, meetings involving a wider range of concerned persons.

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Conclusions

Twenty years ago, the teaching of biology mainly emphasized such descriptive aspects as the morphology, anatomy and taxonomy, of living things, and the teacher's activity in the classroom. The latter took the form of lectures with or without laboratory exercises, which at best involved verification by the pupil of statements made during the course. In most cases, the pupils' activity was essentially reduced to memorization of a great number of facts - a situation clearly reflected in the accompanying examination system. Lastly, the content of the biology courses was often initially defined in the industrialized countries and was then exported without any adaptation to the newly developing countries.

During the last two decades, the subject of biology has expanded rapidly and is still expanding, both as regards knowledge of living organisms and the techniques by which this knowledge is obtained. Moreover, there has been an added emphasis on the implication of this knowledge for the general well-being of humanity at large. It is becoming increasingly possible to incorporate this new knowledge in existing biology courses, and both school and university syllabuses show signs of this approach.

The evolution of biology teaching during the past twenty years or so has reflected these changes, and trends almost everywhere have remained more or less similar though their pace has to some extent varied.

It is generally agreed that the starting point for such an innovative process was the Biological Sciences Curriculum Study (BSCS) projects in the United States (1959) followed by the Nuffield Biology Projects in the United Kingdom (1962) where up-to-date knowledge and techniques have been combined with more emphasis on the process of biological investigation and greater encouragement to pupils to learn through experimentation and discovery approaches. Other countries followed suit. As a first step, some of them translated one or other of the versions of the BSCS books, either with or without course adaptation. In some cases, new courses were developed which took advantage of foreign experience and adapted it in the light of local needs, problems and preoccupations. In these efforts, some countries have even successfully tried to adapt their biology teaching to the pupils' capacities. In all these cases, an overall trend has been teaching centred more on the child and his immediate environment.

Such a diversity in the evolution of biology teaching at world level might have brought about some contradiction, or at least heterogeneity, in the positions adopted by the two hundred participants who came to the Uppsala Congress from various countries and represented primary, secondary and university teachers, specialists in educational research and in child psychology, or decision-makers. But the Congress showed, on the contrary, a broad consensus of opinion on several points during the discussion of the twelve trend papers which were presented to the working groups. This consensus forms the basis of the present conclusions.

As regards the place of biology teaching, it was clear to all that biology is an important component of general education; and since it contributes to language training and to the development of the young child, it should commence at primary-school level with effective vertical co-ordination at subsequent levels right up to university entrance. Linked closely with this is the question of horizontal co-ordination. An integrated science course is generally accepted at the

primary level, but at higher levels its philosophy is still questioned. Nevertheless, the fact remains that horizontal co-ordination of biology with sister disciplines is necessary for the sake of effectiveness.

At the level of curriculum preparation, it is generally agreed that curricula should be defined and developed to follow clearly the objectives which are to be achieved through them. For every country, such objectives should at the same time take into consideration the universal principles of biology and the local character of the biological events the child can perceive. The curricula, therefore, should be centred more on the child's context, motivations, needs and future. They should also take into account the society where the child is to live and where he should receive much information through the mass media. The pupil cannot simply gather and store this knowledge. He should therefore be trained with a view to an informal, prolonged education, during which he can sort out all the necessary information for his use.

A change in teaching methods is therefore necessary, with priority given to direct experience, above all in young children. This does not mean that the discovery method should be pursued without order; it implies rather a progression during which the teacher guides the pupil according to the determined objectives and helps replace rote learning by the elaboration of concepts into organized knowledge which may be improved and extended during pupils' own experiments. Moreover, skills will have to be developed in order to be used outside the classroom. All these objectives can be attained only through the diversification of teaching methods. As to the contents of the curricula, fashions have been noticed everywhere, such as the introduction of molecular biology or ecology, but it is desirable that before accepting or rejecting such trends of content evolution, the importance of these new fields in the training of grown-ups should be assessed, and due consideration given to social, environmental and population biology which, at present, is too often neglected in most curricula.

Lastly, the curricula cannot be considered satisfactory until a careful evaluation has taken place (not only during curriculum elaboration - i.e. concerning a provisional curriculum - but also after the final product, by following the same children for several years in order to assess the real impact). It is obvious that, for the sake of objectivity, those who make this evaluation of curricula should not be those who built them.

At the level of assessment of students' achievements, the ways and means of making such an assessment should be adapted to the new objectives of teaching, in as much as it is desired to replace note learning by the acquisition of know-how. Biology seldom plays an important role in the selection of students and, hence, assessment could be oriented towards some kind of diagnosis, i.e. some kind of relationship between the teacher and the student, so that both may know to what extent teaching objectives have been achieved. Due to the diversity of objectives, the pure and simple recall of data cannot be the main criterion in assessment and the types of assessment trials should be as diverse as possible.

As to the teachers, there are, in most of the countries, two distinct categories of specialists concerned with the evolution of biology teaching: those responsible for curriculum change, on the one hand, and those who teach, on the other. The teachers have often received an old-fashioned training, and even when in-service training exists, it is more scientific than pedagogical. The curriculum innovators are often worried by the slow and ineffective dissemination of innovation among the teachers (it is generally assumed that less than 30 per cent of teachers have access to innovation efforts after several years) and by their lack of motivation for in-service activities. The teachers claim that they are neglected in educational research, for which they feel they have some competence and judgement capacity; they claim that they are confronted with innovations for which they have not been prepared and which they had no change to discuss.

The suggested solution is, on the one hand, to have the teachers participate more closely in educational research, so that their difficulties and reluctance to accept new curricula are known before innovation starts, thus ensuring greater effectiveness; on the other, to see that both initial and in-service training are provided by the same institutions, so that a more coherent

teaching staff is produced. Teachers will thus develop progressively a better knowledge of new educational technology - e.g. audio-visual aids, not only as regards their handling, but also the best way of using them.

The progress made during the last twenty years was achieved partly thanks to international co-operation which has not only fostered useful competition, but permitted greater effectiveness. The role of Unesco must to be acknowledged in this area, but there is still room for improvement so that every country can proceed with a critical appraisal of experiments and errors made elsewhere and, at the same time, question some aspects of its own teaching when confronted with different ideas. Within the same country, more exchanges should take place between the various categories of teachers and educators, as well as within the teachers' associations, and even within a school or group of schools. Such a process can contribute, with minimum effort, to the serious improvement of the teacher's training to the great benefit of his students.